VOLUME 30 NUMBER 6

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SPRING MEETING, JUNE 23-26, DETROIT, MICH.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PROCEEDINGS

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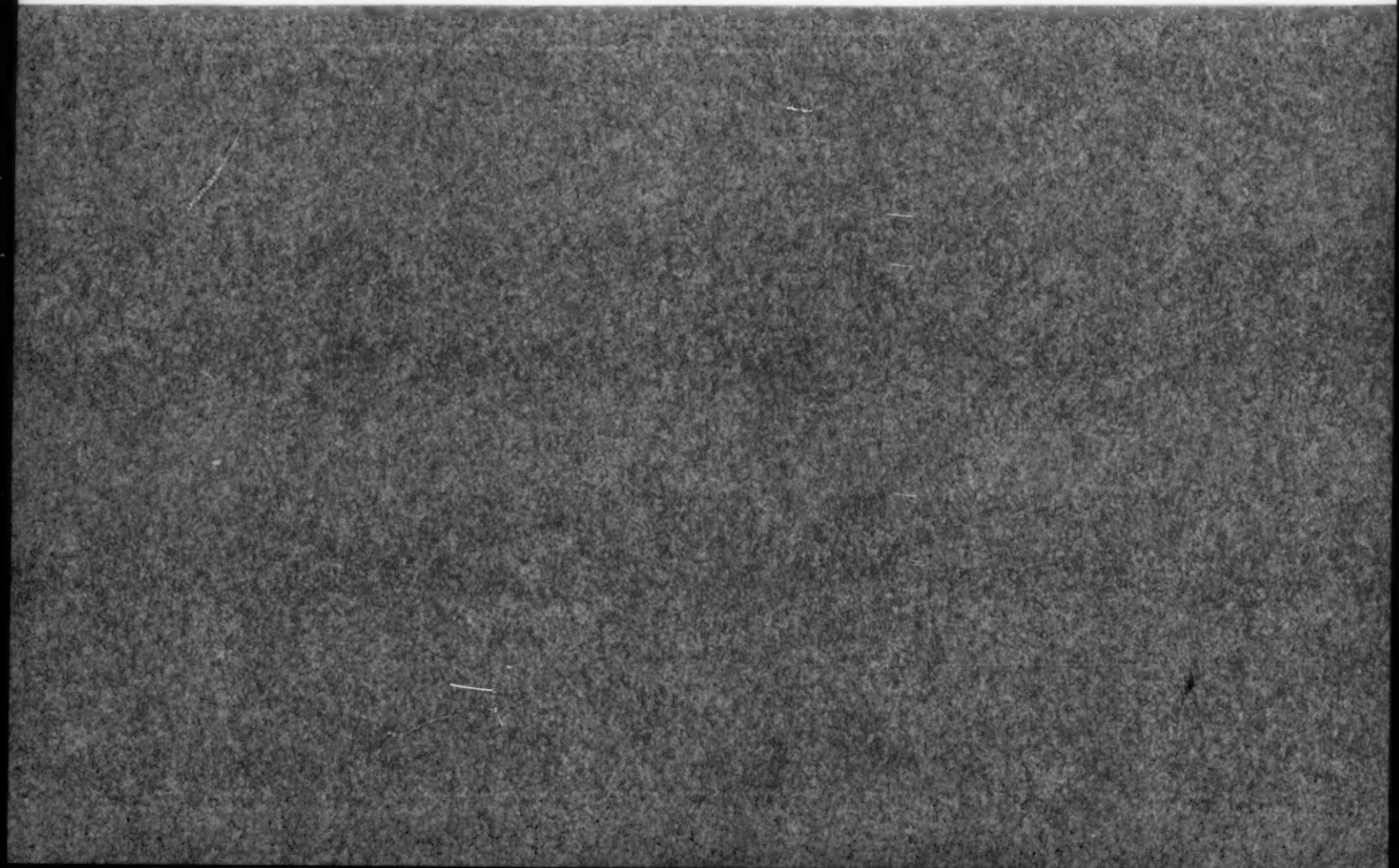

JUNE 1908 VOL. 30 No. 6

THE AMERICAN SOCIETY OF
MECHANICAL ENGINEERS

PROCEEDINGS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
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PROCEEDINGS

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 30 JUNE 1908 NUMBER 6

THE last monthly meeting for the season was held in the Engineering Societies' Building on the evening of May 12, Mr. Fred J. Miller, Vice-President, presiding. The paper of the evening upon "Clutches" was given by Mr. Henry Souther, of Hartford, Conn., member of this Society, of the Society of Automobile Engineers and of the Association of Licensed Automobile Manufacturers. There was a representative audience and the discussion was correspondingly varied and complete. Mr. Souther dealt largely with clutches as used in automobiles, and much of the discussion which followed supplemented what he had to say with descriptions of clutches developed in other fields of work. Mr. Charles R. Gabriel of New York showed a number of lantern slides of clutches used in power press work and Mr. Frank Mossberg of Attleboro, Mass., touched upon the same class of work. Mr. E. H. Neff, New York, and Mr. E. J. McClellan, New York, took up clutches in machine tool work. Others who participated were Mr. Fred Miller, Buffalo, N. Y., Mr. J. J. Bellman, New York, Mr. H. F. J. Porter, New York, and Mr. B. D. Gray of the American Locomotive Co., Providence, R. I.

The paper upon Clutches is to be brought up again for discussion at Detroit and contributed discussion not read at the New York meeting will be presented then, with oral discussion from members present.

Regular Meeting of the Council

May 12, 1908. Mr. P. W. Gates, Vice-President, presiding; and also present: Messrs. Humphreys, Miller, Riker, Wiley, Basford and Hutton. In the absence of the Secretary on official business in Washington the Honorary Secretary acted in his behalf.

As the following failed to avail of their election to membership within the statutory period of six months, their election was declared void:

F. C. Wilkes; G. R. Fairchilds; M. D. Gould; G. H. Gerrish; L. Menzl; Tanoshi Saka; Leonard Goodwin; Arthur F. Miller; E. H. A. Peterson; M. McLean Goldie; Francis W. Jackson.

The Honorary Secretary appointed to represent the President of the Society at the last conference of the four national engineering societies on the conservation of our natural resources reported upon resolutions to be presented at the conference of the Governors of the United States, the text of which is published elsewhere in this number.

The following appointments of Honorary Vice-Presidents to represent this Society and its President were confirmed:

Prof. F. R. Hutton, to represent the Society at the conference of the four national engineering societies on the Conservation of Natural Resources, May 9.

Prof. Ira H. Woolson, at the dedication of new buildings of the College of the City of New York, May 14.

Mr. Geo. M. Brill, at the Thirty-first Convention of the National Electric Light Association in Chicago, May 18.

Mr. Gardner Tufts Voorhees, at the International Congress of Refrigerating Industries in Paris, Sept. 17–23. Mr. Voorhees has also been appointed as a delegate by the Department of State of the National Government.

Messrs. Laurence V. Benét and Gustave Canet, at the Sixtieth Anniversary Banquet of the Society of Civil Engineers of France.

Mr. Laurence V. Benét, at a conference in Paris on Standardization of Gas Pipe and Pipe Threads, under the auspices of the Société Technique del' Industrie du Gaz. This conference will convene at Paris, June 23.

Messrs. Alex C. Humphreys and Fred J. Miller were appointed representatives of the Society on the council of the American Association for the Advancement of Science, pursuant to the request of the association.

Addition to By-Law 18 as outlined last month approved and adopted.

Changes in standards of the Society approved under headings, "SAD," "SAFM" and "SNB" relating to office procedure in handling of dues and other monies.

Resolutions passed favoring coöperation with the National Association of Master Steam and Hot Water Fitters in preparing Standards for Flanged and Threaded Connections.

Resolved that candidates reported from the Membership Committee for election by the Council previous to the Detroit meeting be referred to the Executive Committee of the Council with power.

The meeting adjourned to meet in Detroit on the opening day of the semi-annual meeting.

LETTER FROM PRESIDENT HOLMAN ON RESEARCH COMMITTEE

To the Membership:

I am desirous of making appointments on the Research Committee, and in order that I may select members best qualified for this important work, I respectfully request each member of the Society to suggest a name or names for this important committee. In making these suggestions the accomplishments, the variety of interests and geographical location of the candidates should be borne in mind. Reasons should also be given which recommend the person for the position on the Committee, as this will materially aid me in deciding upon the suitability of the person proposed.

The amendments to the By-Laws, recently adopted to provide for the creation and work of this Committee, are published below.

The Research Committee shall consist of five Members, Associates or Juniors. The term of office of one member of the Committee shall expire at the end of each Annual Meeting.

This Committee shall have supervision of such research or investigations as may be directed or approved by the Council; shall correspond and collaborate with committees of kindred technical, scientific or other societies; shall keep in touch with researches conducted in other countries, which are of value to the engineer; and shall report the same quarterly to the Council.

The Committee will be expected to maintain a system of announcement of results of research; and the trend of investigations in any field, which will be of value to the engineering profession.

Gifts or bequests to the Society for the conduct of research or investigation shall be expended under the direction of the Council and shall be kept separate from other Society funds.

It is earnestly desired that each member give careful thought to the suggestions for appointments, and that the proposals of names may be forwarded promptly to the Secretary.

Very truly yours,
M. L. Holman,
President.

A. S. M. E. REPRESENTED AT CELEBRATION OF THE SOCIÉTÉ DES INGÉNIEURS CIVILS DE FRANCE

At the banquet given in honor of the Sixtieth Anniversary of the Société des Ingenieurs Civils de France, on May 16, this Society was represented by Monsieur Laurence V. Benét. The occasion was a most agreeable one, and responding to the toast, "The American Society of Mechanical Engineers" Mr. Benét said:

MONSIEUR LE PRESIDENT:

MESSIEURS ET CHERS COLLEGUES: Je me suis senti par trop flatté, en recevant du Président de l'American Society of Mechanical Engineers une depêche me priant de représenter notre corporation au soixantième anniversaire de la Société des Ingénieurs Civils de France. Il aurait mieux fait d'envoyer un orateur expérimenté pour transmettre ses félicitations et ses voeux à l'occasion de cette belle fête. Mais, hélas! si la télégraphie sans fils n'émerveille plus le monde, la transportation transatlantique sans bateau n'est encore de notre temps.

En vous souhaitant, Messieurs, au nom de mes collègues américains, une autre période de soixante années de prospérité et de brilliants achèvements, je n'affirme qu'une fois de plus les relations cordiales qui depuis si longtemps unissent nos deux sociétés. L'exposition de 1889, quand nous avons pour la première fois connu la généreuse hospitalité des Ingénieurs Civills de France, sous la présidence de M. Eiffel, n'était qu'une inspiration pour notre exposition de '93, et en 1900 nous sommes encore venus en France, où, sous la Présidence de M. Canet, notre entente cordiale professionnelle a reçu sa consécration définitive. Et maintenant, Messieurs, il reste encore, à nous, par une nouvelle manifestation internationale et digne de notre grand pays, de vous montrer à quel dégré nous avons pu continuer à contribuer au développement industriel du monde.

Nous, ingénieurs d'outre mer, nous serons toujours reconnaissants à nos confrères de France. C'est à vos savants, à vos mathématiciens et à vos ingénieurs que nous devons une très grande partie de nos connaissances scientifiques. On ne peut même pas lire les ouvrages techniques américains sans y voir l'influence des savants français dans leurs lucides développements des thèses. D'un autre côté, nous avons pu prêter à la France un concours très important dans son progrés industriel. Ce sont nos machines-outils et l'inspiration de notre organisation de la production intensive qui ont complété ces ateliers, ces usines et ces chantiers qui sont actuellement la gloire de votre belle patrie?

A ne prendre qu'une seule industrie, celle de l'automobile, dans laquelle la France a montré le chemin au monde entier, c'est grâce aux machines américaines qu'elle a pu en quelques courtes années couvrir les routes de tous les pays de ces engins remarquables de locomotion.

Et au cours du progrés gigantesque réalisé dans tous les travaux de génie aux quatre coins du monde, nos deux sociétés, par leurs travaux et par leur dissémination de renseignements professionnels et de connaissances techniques, ont rendu des services impossibles à évaleur.

Monseiur le Président, et mes chers collégues, je léve mon verre à la prospérité des Ingénieurs Civils de France, à l'entente cordiale professionnelle entre nos deux pays, et à notre conqpête de la nature par les forces de la nature même.

GAS POWER SECTION

The developments of the past few years have demonstrated the possibility of commercial power generation by gas engines and producers direct from the fuel, and the data obtained from the operation of the various units installed have shown that future progress is to depend on a more detailed study of the various phases of the general problem than might interest any one of the great engineering societies. To permit the free discussion of all sorts of questions at issue, in however minute a detail, or in however general a manner, and to secure every point of view in the discussion, the Gas Power Section of The American Society of Mechanical Engineers was organized. Attention is particularly called to the fact that papers may be prepared, meetings attended, papers discussed and copies of Proceedings received by persons who are not members of The American Society of Mechanical Engineers or not qualified to become members. This will permit participation in discussions of gas power problems not only by engineers, but also by mechanics, draftsmen, salesmen and executive officers. An invitation is extended to all of these classes to take part in the work, which has for its sole object the development of what has proved to be the most efficient method of power generation from fuel.

THE LIBRARY OF THE ENGINEERING SOCIETIES

That the Library is one of the important activities of the Society is not generally taken into account by the membership. It is already one of the most complete engineering libraries in the world, containing over 50 000 volumes, and has on file the Proceedings and Transactions of the various engineering and technical societies, as well as all the current foreign and domestic technical periodicals, four hundred and fifty in all.

The combination of the libraries of the three Founder Societies is, however, to be regarded only as the nucleus, the foundation, of the great engineering library of the future, which should contain complete records of engineering and scientific achievement, not only of the present, but those works which constitute valuable historical records of the early years of modern engineering. It is the aim to develop it into a library of world wide influence.

Mr. Henry R. Towne has recently given a valuable collection which contains some of the earliest and most important beginnings

of English engineering literature, and from Mrs. Annie M. Forney, widow of the late Matthias Nace Forney, a member, the Society received Mr. Forney's complete technical library by which it has completed valuable sets of Proceedings. The gift was also replete with books on railroad engineering.

The equipment and facilities of the library, located as it is in the headquarters of engineering—in a fireproof building with every convenience for indexing and caring for its gifts—must recommend it to friends who wish to place scientific and engineering literature or valuable engineering relics where they will be of the widest enduring influence.

It is maintained as a free reference library and with the ideal of being of the greatest use and benefit to the profession, regardless of society affiliations. Librarians are always in attendance to give assistance in locating information, and it is the expressed aim of the Engineering Societies to make it of permanent and ever increasing service.

FIFTIETH ANNIVERSARY OF MICHIGAN AGRICULTURAL COLLEGE

It is desired to place on record in the Proceedings of the Society a statement of the fiftieth anniversary of the founding of the Michigan Agricultural College. This was the first of the so-called Agricultural Colleges and was established a number of years before the Morrill Land Grant Act went into effect. Engineering work was inaugurated there in 1885 and Prof. R. C. Carpenter was instrumental in building up the course of study in this department. At present there is an enrollment of over 400 students in engineering. The anniversary ceremonies were held in May 1907. The principal features were addresses upon the College and State, reminiscences by former students and the conferring of degrees. The degree of LL.D. was conferred upon Prof. R. C. Carpenter, member of the Society, Ithaca, N. Y., and Prof. M. E. Cooley, former Vice-President of the Society and Dean of the Department of Engineering, University of Michigan, Ann Arbor, Mich.

THE SPRING MEETING AT DETROIT

GENERAL NOTES

The semi-annual meeting at Detroit will open on Tuesday evening, June 23, with addresses of welcome and response by President Holman followed by an informal reception; and will close on Friday with a professional session in the morning and an excursion in the afternoon and evening.

As previously announced, the Society for the Promotion of Engineering Education and the Society of Automobile Engineers will hold sessions simultaneous with those of The American Society of Mechanical Engineers and there will be the added pleasure of meeting the members of these societies and attending such of their sessions as desired. There will also meet in Detroit the Society of Gas Engine Manufacturers, giving still greater interest to the occasion.

In this number of Proceedings is published a complete list of papers to be presented. Of these, four are upon the general subject of the conveying of materials which, with the discussions expected to follow, will constitute a symposium more complete than any treatment of this important branch of engineering which has hitherto appeared. These, together with the other papers, cover a wide field, and discuss topics of foremost importance to the engineering profession.

The paper upon Clutches presented by Mr. Henry Souther at the May meeting will come up for discussion at Detroit, and it is expected that many automobile engineers will be present to express their views.

The Secretary cannot undertake to reserve rooms for members or guests at the hotels in Detroit. Members should communicate direct with the hotels at which they wish to stop.

The Secretary regrets that after repeated efforts it has been impossible to secure reduced rates for the transportation of the members of the Society to and from the Convention, owing to legislative enactments in several states establishing a two cent rate, and owing also to the inter-state tariff law. Read the transportation notice carefully.

One or more private Pullman sleeping cars will be reserved on each of three trains from the East and on one train from Chicago. These reservations will be made only in the event that the number of applications received for Pullman accommodations reach the minimum set by the company. Address applications for these reservations to S. E. Whitaker, Office Manager of the Society.

The official headquarters will be opened in the Hotel Cadillac at noon Tuesday, June 23, and maintained throughout the meeting. Members and guests are requested to register as early as possible so that they may receive badges. No guest will be registered unless he brings with him a letter of introduction from the member whose guest he is, or unless the member personally registers for him. The headquarters and general management will be in charge of S. E. Whitaker, Office Manager, Badge No. 5.

The excursions provided for this meeting are most notable and include visits to view the remarkable engineering work in progress near Detroit. Events in connection with this work, which will be impressive and even spectacular, have been planned to occur at the time of the convention. Every opportunity will be afforded to visit centers of engineering activity and points of scenic beauty in which Detroit and vicinity abound.

The Local Committee at Detroit consists of Mr. Alex Dow, *Chairman*, Mr. W. J. Keep, Mr. W. S. Russel, Mr. F. E. Kirby, Mr. C. G. Herbert, Mr. T. H. Hinchman, Jr., Mr. H. E. Coffin, Mr. A. C. Pessano and Mr. S. G. Barnes.

The officers of the Society and officials of the meeting will be designated by the following badge numbers:

No. 1 Mr. M. L. Holman, *President*
No. 2 Hon. Wm. H. Wiley, *Treasurer*
No. 3 Mr. Calvin W. Rice, *Secretary*
No. 4 Mr. Lester G. French, *Editor*
No. 5 Mr. S. Edgar Whitaker, *Office Manager*
No. 6 Mr. Alex Dow, *Chairman Local Committee*
No. 7 Mr. W. J. Keep
No. 8 Mr. W. S. Russel
No. 9 Mr. F. E. Kirby
No. 10 Mr. G. H. Herbert
No. 11 Mr. T. H. Hinchman, Jr.
No. 12 Mr. H. E. Coffin

No. 13 Mr. A. C. Pessano
No. 14 Mr. S. G. Barnes

Two editions of the printed Members' Register will be issued and distributed at the Convention. The first at the morning session on Wednesday and the second at the reception on Thursday. The names registered up to nine o'clock on Tuesday evening will be included in the first edition. The second edition will close at noon on Thursday.

Application for membership may be made on the standard form which can be procured at the Registration Desk. The applications should be sent to the Secretary who will communicate with the references of the applicants and submit them to the Membership Committee for action.

PROGRAM OF THE SPRING MEETING

By mutual arrangement the following Societies are holding their conventions simultaneously with the A. S. M. E.

THE AMERICAN SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION,

THE SOCIETY OF AUTOMOBILE ENGINEERS,

THE SOCIETY OF GAS ENGINE MANUFACTURERS.

A cordial invitation is extended by the A. S. M. E. to each member of the above named societies to attend all the sessions, and the Detroit Local Committee also invites the members of the above societies to all the entertainments.

OPENING SESSION

Tuesday evening, June 23, at 9.00 o'clock

In the Convention Hall of Hotel Cadillac.

Address of welcome.

Response by M. L. Holman, President of the Society.

A social reunion and informal reception will be held after the opening addresses which will give an opportunity for members and guests to meet the friends of Detroit and exchange greetings. Ladies will be especially welcome.

SECOND SESSION

Wednesday morning, June 24, at 9.30 o'clock.

Business Meeting. Reports of the Tellers on Election of Members and Reports of Standing and Special Committees. New Business can be presented at this Session.

SYMPOSIUM ON MACHINERY FOR CONVEYING MATERIALS

HOISTING AND CONVEYING MACHINERY, G. E. Titcomb.

CONTINUOUS CONVEYING OF MATERIALS, S. B. Peck.

THE BELT CONVEYOR, C. Kemble Baldwin.

CONVEYING MACHINERY IN A CEMENT PLANT, C. J. Tomlinson.

BELT CONVEYORS, E. J. Haddock.

THIRD SESSION

Wednesday afternoon, at 2.00 o'clock

CONVEYING MATERIALS, discussion continued

THERMAL PROPERTIES OF SUPERHEATED STEAM, Prof. R. C. H. Heck.

A RATIONAL METHOD OF CHECKING CONICAL PISTONS, Prof. G. H. Shepard.

A JOURNAL FRICTION MEASURING MACHINE, Henry Hess.

LECTURE

Wednesday evening at 8.30 o'oclock

CONTRIBUTIONS OF PHOTOGRAPHY TO OUR KNOWLEDGE OF STELLAR EVOLUTION, by Prof John A. Brashear, Astronomer and Scientist, Allegheny, Pa.

EXCURSION

Thursday morning, June 25 at 10.00 o'clock

Through the courtesy of Mr. A. C. Pessano, Member of the Detroit Local Committee and President and General Manager of the Great Lakes Engineering Works, the Society will be entertained by a steamer trip to the Great Lakes Engineering Works to witness the launching of the 10 500-ton steamer, the William B. Meacham, and to see the sinking into place of the fourth section of the Detroit tunnel.

FOURTH SESSION

Thursday afternoon, at 2.30 o'clock

THE SURGE TANK IN WATER POWER PLANTS, Raymond D. Johnson.

SOME PITOT TUBE STUDIES, Prof. W. B. Gregory and Prof. E. W. Schoder.

COMPARISON OF SCREW THREAD STANDARDS, Amasa Trowbridge.

IDENTIFICATION OF POWER HOUSE PIPING BY COLORS, Wm. H. Bryan.

GAS POWER SECTION

Thursday afternoon, June 25, at 2.30 o'clock

Simultaneous with the Fourth Regular Session

THE BY-PRODUCT COKE OVEN, W. H. Blauvelt.

POWER PLANT OPERATION ON PRODUCER GAS, G. M. S. Tait.

HORSE POWER, FRICTION LOSSES AND EFFICIENCIES OF GAS AND OIL ENGINES, Prof. Lionel S. Marks.

A SIMPLE METHOD OF CLEANING GAS CONDUITS, W. D. Mount.

RECEPTION

Thursday evening, at 9.00 o'clock

The reception will be held at the Hotel Cadillac. This is the distinctively social feature of the meeting and the attendance of the ladies is particularly desired. It is urged that no one shall remain away because the exigencies of travel have made evening dress inconvenient.

FIFTH SESSION

Friday morning, June 26, at 9.00 o'clock

ECONOMY OF HIGH-SPEED ENGINES, F. W. Dean and A. C. Wood.

AIR LEAKAGE IN STEAM CONDENSERS, Thos. C. McBride.

CLUTCHES, Henry Souther. Discussion continued from May Meeting.

EXCURSION

Friday afternoon, at 3.00 o'clock

Excursion on the Detroit River on Steamer Britannia.

RAILWAY TRANSPORTATION NOTICE

Arrangements for hotel, transportation and sleeping car accommodations should be made personally by each person.

SPECIAL TRAIN ARRANGEMENTS

One or more private Pullman sleeping cars will be reserved on each of three trains from the East. These reservations can be made however only in case the number of applications received for accommodations reach the minimum set by the Pullman Company. Address applications to Mr. S. E. Whitaker, Office Manager.

The first train selected is the Wolverine via N. Y. C. R. R., with buffet, smoking and library car, and dining car. The Pullman sleeping car will run through to Detroit without change. This train will leave New York on Monday and arrive in Detroit Tuesday morning. The first session of the convention will be on Tuesday evening.

Lv. New York, Monday, June 22 ..... 4.30 p.m.
Lv. Boston ..... 1.45 p.m.
Lv. Albany ..... 8.00 p.m.
Lv. Schenectady ..... 8.31 p.m.
Lv. Syracuse ..... 11.40 p.m.
Ar. Detroit, Tuesday June 23 ..... 8.15 a.m.

The second train selected is the Chicago Limited via Pennsylvania Railroad, with smoking and dining cars. The Pullman sleeping car will run through to Detroit if 18 reservations are made.

Lv. New York, Monday, June 22 ..... 4.55 p.m.
Lv. North Philadelphia ..... 7.08 p.m.
Lv. Washington ..... 5.45 p.m.
Lv. Baltimore ..... 7.05 p.m.
Ar. Detroit, Tuesday, June 23 ..... 4.10 p.m.

The third train selected is the Chicago Toronto Express via Lehigh Valley Railroad. This line allows stop-over at Niagara Falls on individual tickets.

Lv. New York, Monday, June 22 ..... 5.40 p.m.
Lv. Philadelphia ..... 6.30 p.m.
Lv. Bethlehem ..... 8.33 p.m.
Lv. Buffalo, Tuesday, June 23 ..... 5.35 a.m.
Lv. Niagara Falls ..... 7.10 a.m.
Ar. Detroit, Tuesday June 23 ..... 1.20 p.m.

An alternative train is the Buffalo and Cleveland special via New York Central Railroad, leaving New York at 8 p. m. Monday, and arriving in Detroit at 1.30 p.m., Tuesday.

FROM CHICAGO

The train out of Chicago, the N. Y. & Boston Special via Michigan Central upon which a special car will be run if the number of reservations warrants it, will reach Detroit in time for the opening session Tuesday evening. It is believed that our members and their guests will be glad to coöperate to secure this additional opportunity for social intercourse with old friends. The schedule will be:

Lv. Chicago, Tuesday, June 23 ..... 10.30 a.m.
Ar. Detroit ..... 5.55 p.m.

REGARDING SPECIAL RATES

The Secretary regrets that after repeated efforts it has been impossible to secure any reduction in the rate of transportation of the members of the Society to and from the convention. Owing to the enactment of two cent fare laws by the legislatures of a number of States in the territory included under the jurisdiction of the Central Passenger Association, and by reason of these material reductions in their passenger revenue, the transportation lines in this Association are compelled to modify the arrangements they have made for many years for convention travel.

The trans-Continental Passenger Association announce one first-class thirty-day fare for the round trip from California, for instance, to Chicago, and return $72.50; to St. Louis and return $67.50. These tickets are on sale three days only, June 5, 6 and 19, and may be purchased, going via any regular direct route, returning via the same or any other regular direct route. Stop-overs will be allowed between the California line and Chicago. The purchaser must reach his destination within 10 days of sale. Tickets are good for return within 90 days of date of sale. This Association also announces the regular nine months rates to Chicago and St. Louis; these approximate two cents per mile in each direction, or about one fare and one-third for the round trip. The territory includes:

California, Nevada, Oregon, Washington and west of and including Mission Junction, B. C., including also Kootenay common points, Nelson, Rossland, Sandon, Caslo, and Grand Forks, B. C.

HOTEL ACCOMMODATIONS

The Cadillac has been selected as the official hotel for the Detroit meeting, June 23–26, 1908, the headquarters of the Society during the convention, and the meeting place for the professional sessions.

Members who expect to attend the meeting and desire accommodations at any of the hotels listed below will please communicate directly with the house they select as to what they will require. They are advised to do so as early as convenient, thus avoiding the chance of being disappointed as to the accommodations they may desire.

HOTEL CADILLAC

American plan, room without bath, $3.50, $4 to $4.50, each person. Room with bath, $4, $4.50, $5 to $8, each person. European plan; single room without bath $2, $2.50 and $3 per day, each person; single room with bath $3, $3.50, $4, $5 and $6 per day, each person. A special rate of $3 per day each person, American plan, and $2 per day, each person, European plan, will be made where two or more persons occupy a room without bath.

HOTEL PONTCHARTRAIN

Located on Cadillac Square, at the corner of Woodward Avenue, and about five minutes walk from headquarters.

European plan, room without bath $2 and $2.50 per day for one person; for two persons, $3 and $4 per day. Room with bath $3, $3.50, $4 and $5 per day for one person; for two persons $5, $6, $7 and $8 per day.

The Pontchartrain is a new hotel and is thoroughly up to date in its equipment and accommodations.

THE TULLER

Located at Adams Avenue and Park Street, about five minutes walk from headquarters.

European plan, $2 per day for one person occupying a room alone; $1.50 per day for each person when two occupy a room. Every room is connected with bath.

HOTEL NORMANDIE

Located at Congress Street and Woodward Avenue, within five minutes walk from headquarters.

American plan, rooms without bath, single $2.50 to $3 per day, double $4.50 to $5.50 per day; rooms with bath single $3 to $4 per day, double $5 to $7 per day. European plan, rooms without bath, single $1 to $2 per day; double $1.50 to $3 per day; rooms with bath single $2 to 2.50 per day, double $3 to $4 per day.

ENTERTAINMENT AT THE SPRING MEETING

At the Spring meetings of the Society the entertainment features, which afford opportunities for many members to meet who live at a distance from Society headquarters, are always to be regarded as important functions and this year these opportunities promise to be of even greater interest than in previous years.

Besides the usual informal gathering on Tuesday evening and the reception on Thursday evening, there will be an entertaining lecture on Wednesday evening by Professor Brashear, on "Contributions of Photography to our Knowledge of Stellar Evolution." This is to be given under the joint auspices of the members of this Society and of the Society for the Promotion of Engineering Education.

Arrangements have also been completed for two excursions and opportunities will be offered for many shorter trips to points of interest.

On Thursday morning, through the courtesy of Mr. Antonio C. Pessano, Member of the Detroit local committee and President of the Great Lakes Engineering Works, the Society is to be the guest of his company on a trip by steamer to Ecorse, to witness the launching of a 10 500-ton steamer. The boat which is to convey the party to the works will leave the foot of Third Street (Michigan Central Dock) at 10:00 a.m. on Thursday morning, June 25, and it is planned to return at about 12 o'clock.

The boat to be launched is one of the largest of the Lake steamers, 552 ft. long and 56 ft. beam. It is built for the Frontier Steamship Company and is to be christened William B. Meacham after the Cincinnati partner of the firm of Rogers Brothers.

Work upon the boat is being rushed and the date of the launching has been set ahead to give the members and their friends an opportunity to witness a sight that will be one of the most impressive they have seen in many years. One of the peculiarities of the launching is that the vessel is to be launched sidewise

Attractive as this feature is sure to prove, the visiting members will have additional reason on this trip to feel that they are in the hands of their friends. Another exhibition has been arranged for

their entertainment during the return from the launching, at the site of the Detroit tunnel now under construction for the Michigan Central R. R.

Through the interested efforts of Mr. W. J. Wilgus, Member of the Society and of the advisory board of engineers for the tunnel, a section of the tunnel, known as the fourth section, will be floated into position and sunk within view of the returning visitors.

The Detroit tunnel and approaches will be 2½ miles long, the river section being ½ mile long, constructed by sinking steel sections on a previously prepared foundation in a dredged trench. The section to be sunk on June 25, is 262 ft. long, 64 ft. wide and 31 ft. deep, and it is safe to say that the spectators will regard this as an event long to be remembered.

On Friday afternoon a second excursion is to take place on the steamer Britannia, tendered by the Detroit, Bell Island and Windsor Ferry Co., through Mr. F. E. Kirby, member of the Detroit Local Committee. The Britannia will leave at three o'clock, steam around Belle Island, thence down the river to the lime kilns, where the visitors may look at the construction work of the new tunnel; thence to Bois Blanc Island where it is proposed to serve supper.

For the shorter trips to the various plants and other places of interest about Detroit it has appeared to the Local Committee that the most feasible method would be by means of small parties made up from time to time in accordance with the wishes of the visitors. Opportunity will be offered for inspecting the automobile factories, the factory of the Burroughs Adding Machine Co., the plant of Parke, Davis and Co., manufacturing chemists, and others. The latter is the largest plant of its kind in the world, and contains many things of unique interest. In the mechanical department special machinery is used in great variety, such as capsule machines, compressng machines of the punch and die type, etc. Of scientific interest is the biological laboratory where the various serums for the treatment of disease are prepared.

The Burroughs Adding Machine factory is the largest in its line in the world. It turns out one finished machine every 7½ minutes. It is modern throughout with the best possible facilities not only for work but for pleasure. To this end a gymnasium is maintained. A point of interest is an instruction school where experienced inspectors train students from the factory as mechanical experts. The advertising, sales and purchasing departments are all of interest because of their carefully developed business systems.

ENGINEERING SOCIETIES PARTICIPATE IN THE CONFERENCE ON NATURAL RESOURCES

At the conference on the Conservation of Natural Resources held at the White House in Washington, May 13-15, in response to the invitation of the President of the United States, there were present the Governors and their appointed delegates, members of the Cabinet and Supreme Court, Senators, Congressmen and representatives of the leading engineering, scientific and educational societies of the country.

The four national engineering societies were represented by their presidents and secretaries, respectively. Charles Macdonald, President, and Charles Warren Hunt, Secretary, of the American Society of Civil Engineers; John Hays Hammond, President, and Dr. Joseph Struthers, Assistant Secretary, of the American Institute of Mining Engineers; M. L. Holman, President and Calvin W. Rice, Secretary, of The American Society of Mechanical Engineers, and Henry G. Stott, President, and Ralph W. Pope, Secretary, of the American Institute of Electrical Engineers.

The engineering and technical press were represented by Charles Whiting Baker, Editor, *Engineering News*; Charles Kirchhoff, Editor, *Iron Age*; T. C. Martin, Editor, *Electrical World and Engineer*, and Walter R. Ingalls, Editor, *Engineering and Mining Journal*.

The engineering profession was further represented in the following delegates, chosen either by the Governors, or as representatives of organizations.

Otto von Geldern, California; Thomas W. Jaycox, Colorado; Isham Randolph, Illinois; Lyman E. Cooley, Illinois; John B. Atkinson, Kentucky; Col. Jas. A. Ockerson, Missouri; J. E. Sirrine, South Carolina; Mem. Am. Soc. C. E.

Paul A. Fusz, Montana; Mem. Am. Inst. M. E.

Prof. Geo. F. Swain, Massachusetts; Andrew Carnegie; Mem. Am. Soc. M. E.

John H. Finney, Georgia; Alonzo Gartley, Hawaii; J. W. Porter, Kentucky; W. C. Barnes, New Mexico, H. S. Putnam; Mem. Am. Inst. E. E.

The total representation by members of the four national engineering societies was 25. Emphasis is laid upon this point in the hope that the engineering profession may recognize the duty it owes to the country to participate in this movement, and all the more so because it is an engineering problem.

On the evening of May 12, previous to the convening of the delegates at the conference, a dinner was tendered to the presidents of the national engineering societies by the members of the Washington Society of Engineers, in coöperation with the Washington Society of Civil Engineers. This dinner was attended by a large number of prominent engineers and several notable speeches were made indicating the interest of the engineers in the conservation problem and their desire to coöperate in every possible way for the preservation of the country's resources. This Society was represented at the dinner by President M. L. Holman and Secretary Calvin W. Rice. In his speech President Holman said, among other things:

> The engineering profession has been honored by invitations to the four national societies to be represented at this conference, and the presidents of these societies have been invited to participate. The event is one which will be recorded in history, and the result of the conference will be the guideboard marking the fork of the road, where the nation takes the road leading to prosperity or continues like the prodigal son, to waste its inheritance in riotous living.

CONFERENCE AT THE WHITE HOUSE

The conference met on the morning of May 13 in the East Room of the White House. The audience of about 400, representative of every section of the country and of almost every professional and industrial activity, was one of the most notable and distinguished ever assembled.

It is inevitable, also, that it will mark one of the great movements for the welfare of the human race. The bounteous stores of nature have been ruthlessly wasted. Some time and in the very near future, they will not be adequate to our needs. Some time they will be gone. A few clear-minded scientists and engineers have read the signs of the times, aroused the interest of the President and other officials, and through this conference have attracted the attention of the people.

And what is more important, it is to be hoped they have awakened to active interest the engineers, the men qualified to grapple with the problem of the preservation, the economical use, and where possible the development of nature's stores, for the sustenance of those who are to follow us.

The opening address by the President sounded a new note in national affairs: an appeal for the perpetuity of the nation, the welfare of posterity and devotion to public interest by the present generation. He said:

> The time has come to inquire seriously what will happen when our forests are gone, when the coal, the iron the oil and the gas are exhausted, when the soils shall have been still further impoverished and washed into the streams, polluting the rivers, denuding the fields, and obstructing navigation—Any right thinking father earnestly desires and strives to leave his son both an untarnished name and a reasonable equipment for the struggle of life. So this nation as a whole should earnestly desire and strive to leave to the next generation the national honor unstained and the natural resources unexhausted.

The first session was devoted to the Mineral Resources of the country and addresses were made by Andrew Carnegie Honorary Member American Society of Mechanical Engineers on "The Conservation of Ores and Related Minerals;" by Dr. I. C. White on "The Waste of our Fuel Resources;" and the general discussion was opened by John Mitchell.

The second and third sessions were given to the subject of Land Resources and addresses were made by James J. Hill on "The Natural Wealth of the Land and its Conservation;" by Professor T. C. Chamberlain on "Soil Wastage;" by R. A. Long on "Forest Conservation;" by ex-Governor George C. Pardee on "Resources Related to Irrigation" and by Hon. H. A. Jastro on "Grazing and Stock Raising;" the general discussion was opened by ex-Senator Carey.

At the fourth session Water Resources were discussed and formal opening statements were made by Dr. George M. Kober on "Conservation of Life and Health by Improved Water Supply;" by Professor Emory R. Johnson on "Navigation Resources of American Waterways; by H. S. Putnam, Member American Institute of Electrical Engineers, on "Conservation of Power Resources." These addresses were followed by a general discussion.

The final session was devoted to general discussion of the subject of the Conservation of our Natural Resources.

Mr. Carnegie, Honorary Member of the Society, made an address of which we give a short résumé

> From 1820, the date of the beginning of active coal mining in the U. S. until 1895, 4 000 000 000 tons were mined by methods so wasteful that some 600 000 000 tons were either destroyed or allowed to remain in the ground forever inaccessible. Between 1896 and 1906, as much coal was taken from the earth as during the preceding 75 years and more than 3 000 000 000 tons were destroyed or left in the ground beyond reach of future use. To this date the actual consumption

of coal has been over 7 500 000 000 tons; the waste and destruction in the neighborhood of 9 000 000 000 tons.

The rate of the consumption of coal doubles during each decade, and unless there be careful husbanding, or revolutionizing inventions, or some industrial revolution, the greater part of the estimated 2 000 000 000 000 tons of coal of our original heritage will be gone two centuries hence. And the methods of consuming coal are still more wasteful than the processes of mining. Not more than 5 to 10 per cent of the potential energy is actually used; the remaining 90 to 95 per cent is absorbed in rendering the smaller fraction available in actual work. In electric heating and lighting plants, it is much more; hardly one-fifth of one per cent or one five-hundredth part of the energy of the coal is actually utilized. These wastes are constantly decreasing through the development of gas-producers, internal combustion engines and steam turbines, but not so rapidly as to affect seriously the estimates of increase in coal consumption.

He touched upon the production of iron, copper, zinc, lead and silver, stating that as the rate of production of iron doubles each decade, by 1938 about half of the original supply of iron ore will be gone, and all the ore now deemed workable will be used long before the end of the present century.

Mr. Carnegie suggested as a remedy the lessening of the demands upon the products. One way of doing this is to substitute water-carriage for rail-carriage. This would reduce the consumption of iron by three-fourths to seven-eighths in the transportation department and at the same time reduce the consumption of coal for motive power 50 to 75 per cent, with a corresponding reduction for smelting.

The use of concrete, simple and reinforced, is decreasing the demand for iron for structural purposes, and the internal combustion engines and gas producers double or triple the power per unit of coal, and permit the use of lignite, culm, slack and inferior coals. The most promising check on coal consumption is the substitution of other power—electrical transmission of water power will doubtless soon affect the increasing drain on our coal.

In the general discussion which followed the reading of the papers, Mr. Calvin W. Rice, Secretary of the A. S. M. E., offered the following:

MR. PRESIDENT:

The Governor of Indiana has asked a question which I think should be very definitely answered, as it is probable there are other gentlemen who are also impressed with the difficulties expressed by him.

For instance, the Governor asks how one may conserve coal, and if it is proposed to stop the mining of coal. I answer, absolutely no. The American people are especially quick to take advantage of superior methods of operation and it is only necessary to point out to the progressive mine operators that it is possible, by improved methods of mining, to secure a greater percentage of the coal than they are now mining. For instance, the Governor of Kentucky has stated that the average number of deaths from accident in the mines of one of the large operating companies of his State is only one death per million tons of coal as compared with six deaths per million tons of coal on the average in the United States. In order to secure these better conditions throughout the country, therefore, it is

only necessary to assist the companies in other states to approach the conditions under which the company in Kentucky is operating. That is the direct benefit of this conference. This method may be followed in the conservation of all our natural resources.

This whole subject divides itself naturally into five parts: first, inventory of our resources; second, discussion of the problem; third, statement of remedies; fourth, education of the people; fifth, legislation.

The spirit of all investigation, statement and legislation should be *constructive* rather than *prohibitive*. That is, instead of demanding that there shall be no coal mined, show how coal can be mined to better advantage; show how to design plants which shall effectively use low grade fuels, thus making a market for the coal now left in the earth, benefiting alike the operator, the miner, and the user of coal. This is the typical answer for all the problems of this kind.

In order to take up the above five steps, I recommend that each Governor immediately appoint a commission and as a suggestion I recommend that the commission be composed of a representative citizen from each of the great professions, legal, medical, and engineering. This Committee of three to lay out an organization for securing information, for holding hearings and promoting discussion, and report to the Governor their recommendations. The education of the people can take place through the several channels available to the Governor, through the public press, associations, the legislature, or otherwise.

The legislation and general benefit to the people will follow as a matter of course after this complete statement before the public.

Resolutions were offered to the conference by the presidents of the four national engineering societies, representing approximately 20 000 American engineers, as follows:

WASHINGTON, D. C., MAY, 1908.

The undersigned, representing approximately 20 000 American engineers, respectfully recommend the following resolutions for adoption by this Conference:

CHARLES MACDONALD,
President, American Society of Civil Engineers.
JOHN HAYS HAMMOND,
President, American Institute of Mining Engineers.
MINARD LAFEVER HOLMAN,
President, American Society of Mechanical Engineers.
HENRY GORDON STOTT,
President, American Institute of Electrical Engineers.

Resolved: That this Conference places on record its conviction that to conserve and protect from waste and destruction the natural wealth of the United States in mines, forests, lands, and waters is of vital necessity to the public welfare. Action in this matter has been too long delayed, and vast loss has resulted in consequence, notably in the destruction wrought by forest fires, by floods, and the ruin of lands whose fertility and crop-bearing power has been lost. This unfortunate destruction of part of the natural wealth with which this virgin continent was originally stored makes it all the more necessary that wise action be taken to check further loss.

2 Though it recognizes the imperative need for prompt action, this Conference is impressed with the difficulty of framing legislative acts which shall result in the largest measure of public benefit. The problems presented are many of them new and unprecedented. It is probable that action by both the Federal Government and the individual States will be essential, and it may also be possible by suitable laws to enlist the aid of private enterprise. But to decide upon the proper distribution of responsibilty and to frame laws which shall not work injury as well as benefit is a matter demanding most careful study and investigation by men of high standing and expert qualifications.

3 While certain individual measures may be already in such shape that action upon them may wisely be taken, this Conference holds that for the guidance of legislators, both State and Federal, a thorough investigation and study should be made by National and State Commissions so constituted that their conclusions and recommendations will be everywhere recognized as authoritative and made solely in the public interest.

4 This Conference, therefore, urges upon Congress and the State Legislatures the enactment of laws authorizing the President and the Governors, respectively, to create National and State Commissions to investigate and report upon what measures should be taken to conserve the National and State natural resources.

5 These commissions should report at the earliest possible date consistent with the thorough performance of their work, in order to enable the President and the Governors to transmit with recommendations their reports to Congress and the State Legislatures for such action as may seem advisable to protect our natural resources from further spoliation and destruction, and to secure such economy in their use as will preserve for coming generations the foundations of prosperity.

6 In order to insure the harmonious coöperation of all the Commissions, this Conference requests the President to call another National Conference at such time as may seem most advisable.

7 To secure the most efficient organization for handling the National problem which the reports of these Commissions will inevitably raise, this Conference recommends for the consideration of the President and Congress the formation of a Department of Public Works to which these and other engineering matters could be referred and to which the State Commissions could apply for information and assistance.

The resolutions that were adopted by the conference were broad in their scope, high in their ideals, and in full agreement with the call to future prosperity issued by the President and the notes of warning sounded by those responding. They advocated commissions, State and National, for the conservation of Natural Resources, laws for the protection of forests; and ended with the strong recommendation for "The enactment of laws looking to the prevention of waste in the mining and the extraction of coal, oil, gas and other minerals with a view to their wise conservation for the use of the people and to the protection of human life in the mines," closing with the sentiment: "Let us conserve the foundations of our prosperity."

NECROLOGY

FERDINAND PHILIPS

Ferdinand Philips was born in Elberfeld, Rhein Province, Germany, in 1850. He was educated at the Königliche Provinzial Gewerbeschule zu Elberfeld, graduating with the highest honors, and at the Königliche Gewerbe-Akademie zu Berlin. At Liege, Belgium, he continued his studies in French, and came to America in 1876. He was first employed by Hoopes & Townsend of Philadelphia as designer and engineer, remaining with them until 1883, when he started the wire nail industry in this country under the name of Philips, Townsend & Company.

In 1899 he invented the Philips Pressed Steel Pulley. In the latter part of 1907 the Philips, Townsend & Company and the Philips Pressed Steel Pulley Works, both of which Mr. Philips was the proprietor, were merged into one corporation under the name of Pressed Steel Pulley Works with Mr. Philips as president and general manager.

Mr. Philips died at his home in Philadelphia, March 26, 1908.

CHARLES D. PIERCE

Charles D. Pierce was born in Oswego City, New York, January 31, 1847. He was educated in the home schools of his town and served an apprenticeship in architecture and building with his father, Henry D. Pierce, from 1864 to 1868. In 1868 and 1869 he took a course in architectural and mechanical drawing in the St. Louis (Mo.) Polytechnic Institute, and served with Stacy and Stone, Architects. Afterward he went to Lawrence, Kansas, as architect and contractor, and from 1873 was engaged continuously as manufacturer of machinery for drilling artesian, oil and gas wells and machinery for prospecting for minerals and developing mines. He was also in charge of machine shop and steam forge operations.

In 1877 he began the manufacture of well boring machinery in Philadelphia; two years later moved to New York where he built the "Pierce Iron Works" in Long Island City, subsequently removing to Jersey City, N. J., where he owned and operated the Pierce Well

Engineering & Supply Co. He patented numerous devices and appliances both in America and foreign countries.

At the time of his death he was Consul General for the Orange Free State. His work of boring artesian wells was carried on extensively in Mexico, Central and South America, the West Indies, and also in Europe, Asia and Africa.

His death occurred April 24, 1908.

FREDERICK CONOVER WARMAN

Frederick Conover Warman was born January 7, 1872, at Rutherford Park, N. J. He was educated in the public and high schools of Washington and entered Lehigh University in 1889, graduating in 1893 with the degree of C.E.

He entered the U. S. Engineer Office at Washington immediately after graduation and served in the capacities of rodman, inspector of dredging, draftsman and transitman in charge of parties on river and harbor and bridge works. In May 1906 he was promoted to the position of assistant engineer, and at this time made designs, drawings and estimates for extensive defenses of Washington, D. C. He was placed in charge of the survey for the Memorial Bridge from Washington, D. C. to Arlington, Va., designed boring machinery and made borings, maps, and estimates for this bridge; designed and constructed Engineer Wharf at Easby Point, D. C., and had charge of survey parties and dredging operations on several rivers and harbors.

In 1899 he was made inspector of reconstruction of Pier No. 4 Aqueduct Bridge, D. C. and later in the same year was placed in local charge as assistant engineer, of the construction of the defenses of Washington, D. C., after which work he was made principal assistant engineer on all river and harbor, and fortification work. This position included much important work in connection with fortification, river and harbor improvements and municipal development in the District of Columbia.

At the time of his death Mr. Warman was chief assistant engineer with charge of the River and Harbor Work of the Fortification Division.

In college he was a member of the Tau Beta Pi fraternity and upon entering professional life became a member of the American Society of Civil Engineers and the American Institute of Electrical Engineers.

Mr. Warman died April 27, 1908.

HISTORY OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PRELIMINARY REPORT OF THE COMMITTEE ON SOCIETY HISTORY

CHAPTER IV

EARLY PROGRESS (*Continued*)

111 Early in the year 1883 an action was taken by the Council of the Society which had an important influence upon its development for a number of subsequent years of its existence, the election of Professor Frederic Remsen Hutton as its Secretary. The selection was made at a meeting held on February 15, 1883, this being an adjourned meeting from the regular Council meeting held at the annual meeting of the Society in November 1882, and thus began the official relations of Professor Hutton with the Society which have continued ever since, in the offices of Secretary, President, and Honorary Secretary. Of the effective work which Professor Hutton was thus enabled to do for the Society mention need not be further made at this point, since the record of the history of the Society from the above date forms the most complete story of that work which can be given.

112 The annual meeting in 1883 was held, as usual, in November, the sessions taking place in the house of the sister society, the American Society of Civil Engineers, at 127 East 23d St., New York, a building since pulled down to make way for the business changes in that part of the city. At this meeting Prof. John E. Sweet, whose important part in the foundation of the Society has already been

Under the direction of the Council the Committee on Society History has arranged to present the results of its investigations to the members of the Society.

The Preliminary Report will appear in the Proceedings of the Society from month to month, and thus enable the matter to be open to comment during its completion. It is especially desired that any member who may be in the possession of facts or information bearing upon the various points as they are thus made public will communicate with the committee, in order that the final and completed report may have the advantage of the collaboration of the membership at large.

recorded, was elected President, a worthy recognition of his services and at the same time an action which materially strengthened the work of the organization.

113 The papers presented at this meeting reflected in an interesting manner the development of certain departments of mechanical engineering.

114 Thus, although the single-valve automatic-engine had actually been designed as long ago as 1876, the engines of Professor Sweet and of Mr. Hoadley having been shown at the Centennial Exhibition, it was not until several years later that engines of this kind entered actively into the market. One of the objections to the control of the speed through the shifting eccentric and single valve had been the increase in the degree of compression at early points of cut-off. At this meeting, however, this objection was shown to be an advantage in a paper by Mr. Harris Tabor, who sought to show that the variation of the compression with the variation of the cut-off really gave the governor an increased control over the speed. The subject attracted considerable attention at the time. The single-valve governor cut-off engine has since been accepted as a type having its adaptability to a definite department of power generation, and the discussion has now only an historic interest.

115 At this meeting Mr. C. J. H. Woodbury presented the important researches of Prof. John M. Ordway upon the influence of non-conducting coverings upon the loss of heat from steam pipes, a series of observations of much value and importance upon a subject hitherto scarcely investigated, although since made the question of elaborate experiment, both in the United States and in Europe. Mr. Thomas R. Pickering also presented a paper upon the importance and value of international expositions to the engineering profession, he himself having been a delegate to nearly every exhibition of this class, and an earnest advocate of their usefulness. The interest of the members thus directed, became important and influential, and subsequent records will show the extent to which its meetings became associated with what the late President McKinley called the "milestones of progress." Thus the Society was represented at Congresses held at Paris in 1889, at Chicago, 1903; again at Paris in 1900, and at St. Louis in 1904.

116 Noteworthy in connection with the New York meeting of 1883 was the trip of the Society to Stamford, Conn., to examine the works of the Yale & Towne Manufacturing Company, Mr. Henry R. Towne, the President of the Company, having thrown the works open to the

members in a most hospitable manner. Not the least of the important results following upon the development of the Society was the opportunity which such visits gave the members of becoming familiar with the methods and equipment of the representative shops in different lines of work in various parts of the country.

117 The summer meeting of 1884 followed the precedent of the Cleveland meeting, being held in the inland city of Pittsburg, Pa., in May. Here the Society received valuable coöperation from the Engineers' Society of Western Pennsylvania, and from the Western Iron Association, and in fact, the local professional societies in all parts of the country followed the lead which had already been established by the Franklin Institute upon the occasion of the Philadelphia meeting, and joined in the welcome extended by the local members of the Society. Upon the occasion of the Pittsburg meeting an important report upon the then vital subject of the development and use of natural gas was prepared by the Engineers' Society of Western Pennsylvania, and presented at a joint session of the two organizations.

118 An important development of the work of the Society resulted from a paper presented by Mr. William Kent upon the subject of boiler tests, this being followed by the appointment of a committee to prepare standard rules for the use of engineers in testing steam boilers. The result was the first of the various standard codes of the Society, codes which have served in all departments of engineering work to which they could be applied since. The boiler testing code has been revised to keep it in accordance with the progress which has been made in the science of steam generation since it was first drawn up, and represents the ripe experience of the most eminent specialists in that important branch of mechanical engineering.

119 Other important papers presented at the Pittsburg meeting were those by Mr. John W. Cloud, investigating the properties of spiral and helical springs, and confirming the formulae devised by Reuleaux; and by Prof. William A. Rogers describing the successful methods devised by him and his associates in the production of screw threads of a high degree of perfection.

120 In November 1884 the annual meeting of the Society was held in New York in a building which was destined for many years to be closely associated with the life of the organization; the house at 12 West 31st St., then the property and home of the New York Academy of Medicine. This building, of which more shall be said hereafter, was one of the fine old-fashioned brown stone residences

originally designed for private use in New York, upon the rear garden of which an extension had been erected making a large meeting hall. This hall, equaling in height two of the stories of the original building, was arranged primarily for the meetings of the Academy of Medicine, but its use was secured for the meeting of the Society upon this occasion, and a familiarity thus obtained with the rooms which were destined, after a few years, to become the home of the Society itself.

121 Following the established custom of the Society, the President delivered an address, remarkable in many ways as a most brilliant essay upon the work of the engineer as viewed in its practical relations by a practical man. It is not possible here to touch upon the many good things in this most stimulating paper, but it may be well in the light of the present status of the engineer in the professional, commercial, and social world to quote his closing hope that the time might come "when he who knows what to do, and how to do it will be regarded as the equal of him who only knows what has been done, and who did it."

122 At this meeting the Committee on Standard Steam Boiler Trials presented its report, together with a code of regulations recommended. This elicited a long and valuable discussion upon a subject in which the interest demonstrated the importance. Mr. Woodbury also presented the second portion of the Ordway experiments upon non-conducting coverings; while Mr. W. F. Durfee and Mr. Robert W. Hunt contributed papers upon the development of the Bessemer process in the United States. Mr. J. F. Holloway was elected President at this meeting.

123 The summer meeting of 1885 took the form of a visit to the sea shore, being held at Atlantic City, New Jersey, in May. Although the city by the sea has since been chosen repeatedly as a place for professional and technical conventions of other organizations the experiment has not been repeated by the Society, and it is generally conceded that localities more nearly associated with engineering work are to be preferred. The principal feature of the Atlantic City meeting was the introduction of the fruitful system of Topical Discussions, these having been arranged by a special committee, and adding much to the interest of the meeting. The Society also at this meeting showed its interest in the growing problem of technical education, drawn forth by a paper by Prof. George I. Alden, upon the methods and work of the Worcester Polytechnic Institute.

124 Although it was broadly intended that the annual meetings should be held in the city of New York, the meeting of November

1885 was a departure from this rule, being held in Boston. In the election for President at this time the choice fell upon Mr. Coleman Sellers; the retiring President, Mr. Holloway, making his address upon the subject of the position and mission of the mechanical engineer. At this meeting there was presented the first formal report of the committee appointed to undertake the formation of a library, and to provide for its maintenance, the results being most encouraging, and the whole subject being one of such importance as to render it advisable to devote to it a separate chapter of this history.

125 Several valuable contributions to professional knowledge resulted from the Boston meeting, among them being the paper by Mr. Wilfred Lewis, upon the transmission of power by gearing. This paper reported the very exhaustive experiments conducted by Messrs. William Sellers & Co., covering the action of spur, spiral, and worm gearing, and also furnishing most reliable and useful data upon a question on which exact information had hitherto been lacking; the efficiency of various forms of gearing. The laws governing the efficiency of worm gearing, concerning which only theoretical discussions had previously appeared, were, by means of these researches, established upon a definite experimental basis.

126 With the extending area covered by the membership of the Society, its scope continued more and more to fill the field included in its title, and to warrant its position as a national organization. This is seen by the fact that the summer meeting of 1886 was held in Chicago, the farthest western point which had yet been selected. Owing to the serious illness of Mr. Sellers, he was unable to attend the convention, and the chair was filled by Vice-President Henry R. Towne.

127 At this meeting Mr. Towne presented a paper treating of the engineer as an economist, the first offered before the Society upon a department of engineering which has been so effectively discussed at its subsequent meetings. Prior to this occasion it had been assumed that the work of the engineer was properly concerned almost wholly with mechanical and constructive problems, and that the domain of business, even including the administration of his own shops, was outside of his sphere. The paper of Mr. Towne showed that the field of the engineer properly included much that had hitherto been excluded from his consideration, and being followed by the papers of Mr. Oberlin Smith, upon inventory valuations, and by Captain Henry Metcalfe upon the system of shop orders used in government arsenals, elicited a discussion which showed the great interest which the broad question had developed. As a result it was decided that such papers

were entirely within the scope of the work of the Society, not in a special and limited department, but broadly, with the consequence that some of the most important contributions to the extensive subject of works-management have since been presented at its meetings.

128 The experimental investigations of Messrs. William Sellers & Co. upon the transmission of power by belting were also presented at the Chicago meeting by Mr. Wilfred Lewis, these experiments forming a contribution to engineering knowledge of value comparable to the previous ones upon transmission by gearing. Another paper of interest was the exhaustive review of the various substitutes which had been proposed for steam, this being presented by Mr. Babcock, and proving of particular value in the light of the later development of the internal-combustion engine. Engineering education also received attention in the thoughtful essay of Prof. C. M. Woodward, upon the training of engineers, in connection with the work at Washington University, St. Louis.

129 The seventh annual meeting, held at New York in November 1886, was again presided over by Vice-President Henry R. Towne, the continued illness of Mr. Sellers preventing him from acting. The presidential address was therefore omitted, and was given to the members later, in the pages of the Transactions. Mr. George H. Babcock was elected President. At this meeting there was given to the profession the report of the Committee on Standard Pipe Threads, the work of the Society in this matter having been conducted in association with the organizations of the manufacturers both of pipe and of pipe-fittings. The result was the practical approval of the Briggs standard, this having been formally adopted by the associations representing the manufacturers, while The American Society of Mechanical Engineers was made the custodian of the standard reference gages prepared for the conservation of the dimensions. According to the established custom of the Society the report and the standards were not adopted as Society standards but the information was placed on record for access and use.

130 One of the Honorary Members of the Society, Professor Reuleaux, of Berlin, presented at this New York meeting, a valuable paper upon the frictional action in various forms of toothed gearing, this eliciting a discussion which renders it a record of Continental and American experience on this subject.

131 The question of the inertia effects of the reciprocating parts of steam engines, a matter which had been before engine builders since the development of the high-speed engine, and which had been

first actively treated by Mr. Charles T. Porter, was made the subject of analysis by Prof. George I. Alden, who provided elaborate tables for the computation of the necessary elements for any specified case. Another paper of importance presented at this meeting, was that by Mr. George H. Barrus, describing results obtained with the steam calorimeter devised by him and first described at the Boston meeting. Economic subjects continued to attract attention, Mr. Towne treating of the intrinsic value of special tools, and Mr. W. E. Partridge showing the extent to which capital was dependent upon high-priced labor.

132 The summer meeting of 1887 showed the extension of the Society in a new direction, turning southward, and gathering at Washington in June. The attractions of the National capital drew an excellent number and although the professional sessions were well attended, the meeting was also notable for its social features, including the brilliant reception tendered to the members by the Hon. Josiah Dent, and Mr. Edward L. Dent, beside trips to Mount Vernon, to Cabin John Bridge, and to the many attractions of the city.

133 Among subjects of recent novelty at the time, presented before the Society at this meeting, may be mentioned the description of the Mannesmann system of rolling tubes from solid bars, presented by Mr. Babcock; and the paper contributed by Mr. James Dredge, of London, upon the subject of incandescent gas lighting, involving the use of the incandescent mantle invented by Dr. Auer von Welsbach. The development of the new navy of the United States lent especial interest to the papers of Mr. H. Ashton Ramsay, and Mr. Joseph Morgan, these discussing the needs of the Navy and the problems of the coast defense of the country. Mr. Kent's paper on profit sharing also attracted attention, and brought out a lively discussion, showing that the interest in the economics of engineering continued to increase.

134 Instead of holding the annual meeting in New York, the Society arranged its convention in November 1887 in Philadelphia, a meeting which, as has already been recorded, took an important place in the social as well as the professional development of the organization. The resident members had enlisted the interest of many important manufacturing and engineering firms, and the local committee included many prominent citizens, all filled with the idea of rendering the gathering memorable in the annals of the Society. The sessions were held at the Continental Hotel, and Mr. Horace See was elected President. The social features of the meeting included, in addition to the reception at the Academy of Fine Arts,

visits to many of the great establishments for which the city is noted; a special trip being made to Bethlehem, to visit the works of the Bethlehem Iron Company, the Lehigh Zinc and Iron Company, and the Lehigh University. Theatre parties were provided for the evening, while a special committee of ladies provided attractive trips for the visiting ladies, a custom which has since been extensively followed.

135 The papers covered a wide range of engineering work, including features in the manufacture of steel, the performance of centrifugal blowers, the friction of steam engines, and the efficiencies of centrifugal pumps. It is interesting to note that the method of stocking and reloading coal, devised by Mr. James M. Dodge, and since become a standard system for many places, was first publicly described at this meeting.

136 Reference has been made to the fact that the Washington meeting showed an extension of interest southward, and this feeling was still further manifested by the decision to hold the summer meeting of 1888 as far south as Nashville, Tennessee. This distance of the meeting point from the headquarters led a number of the Eastern members to unite in the occupation of special cars, this plan having since been followed upon a number of occasions with much satisfaction and advantage. The rapid development of the natural resources of the Southern states, then in its early vigor, rendered the meeting most instructive to the visiting members, and notwithstanding the distance from the homes of most of them, the attendance was excellent. The faculty of Vanderbilt University took especial interest in the convention, and the laying of the cornerstone of the new engineering building of the University made a notable feature in the meeting. The social features of the Nashville meeting included many trips of interest; among which may be mentioned a visit to Fisk University, and a special trip to Belle Meade farm, where General Jackson received the visitors as his guests, and gave them every facility for inspecting this famous home of blooded horses. After the professional sessions were over, the visitors were taken, in a special train, to inspect the newly developed iron works and district of the Sequachee valley, and the city of South Pittsburg; the train then proceeding to Chattanooga, where a reception was held by the Chamber of Commerce, and the battlefields of Lookout Mountain and Missionary Ridge were visited.

137 Papers at the Nashville meeting continued to include economic subjects, the fertile question of cost-keeping entering into the discussion, in consequence of the papers by Mr. Binsse, and Mr.

Fowler. Railroad engineering also began to assume importance in the work of the Society, as represented by papers on car-heating, locomotive boilers, and locomotive valve-gears. Following the precedent of the code for boiler trials, a committee was appointed to formulate a code for duty trials of pumping engines, this following upon a paper by Mr. J. S. Coon, showing the irregular methods then in vogue in making such tests.

138 At the Ninth Annual Meeting of the Society, held in Scranton, Pa., in October 1888, the election of Mr. Henry R. Towne as President was announced, and there was also brought before the Society a question which turned out to be of large importance to many of the members, and which doubtless had a most effective influence upon its future development. This was the announcement of an invitation from the President of the Institution of Mechanical Engineers to such members of the Society as might visit the Paris Exposition of 1889, to hold a meeting in London as guests of the Institution, in connection with the Institution of Civil Engineers, the Iron and Steel Institute, and other professional bodies. Although the matter was presented as being yet under advisement, it soon appeared that it would be carried into effect, and the result was the memorable visit to Europe in 1889, which will be considered in a subsequent chapter. At this meeting the probability of the acquisition of a home for the Society in New York was also discussed, the Secretary's office still being in a business building in the lower part of the city. Negotiations for a portion of the house formerly occupied by Prof. S. F. B. Morse in West 22d St., in connection with the latest of the professional societies, the American Institute of Electrical Engineers, had been initiated, but these were not carried out, and the office of the Secretary, and business headquarters of the Society continued to be in the Stewart Building, at 280 Broadway. At the Scranton meeting the question of the number of meetings of the Society was brought up, some members favoring a single meeting each year. The discussion, which was animated and vigorous, showed the sentiment to be strongly in favor of the continuance of the existing system of two meetings a year, a plan which remained in force.

139 Steam engineering formed an important element in the papers presented at the Scranton meeting, there being papers on steam flow, the determination of moisture in steam, and the cost of steam power. A paper by Mr. Woodbury on electric welding, brought this then novel subject before the members, while the topical discussion on steel drew forth much useful information.

140 The professional visits at Scranton naturally covered the mining of coal and the manufacture of iron and steel, the establishments of the Lackawanna Iron and Steel Company, the Scranton Steel Works, and the Boies Steel Car Wheel Works being inspected, while a number of the members descended the shaft of the Pine Brook Colliery.

141 Before the time set for the summer meeting of the Society, at Erie, Pa. it had become apparent that the European trip would be carried into effect, and at the Erie meeting, in May 1889, the announcement was made that the invitations from the various British societies had been accepted, and that the plans for the trip had been practically completed. The members were also advised that the office of the Secretary had been removed from 280 Broadway to 64 Madison Ave., where the ground floor of the building had been secured, thus providing space for the increasing library, and for reading rooms, as well as for business offices and headquarters.

142 Again the attention of the members was directed to the economics of engineering, a notable paper of this meeting being that of Mr. Henry R. Towne upon gain sharing, this being the first of the various plans for increasing the efficiency of the workman which have since come into such widely extended use. The cost of steam and water power also received active discussion, as did the paper of Mr. James W. See upon standards.

143 The social features of the Erie meeting included a reception, tendered by the local members and their friends, while a sail upon the waters of Lake Erie formed an agreeable element in the gathering.

HOISTING AND CONVEYING MACHINERY

INTERMITTENT TYPE OF APPARATUS

By George E. Titcomb, Philadelphia

Non-Member

The development of modern hoisting and conveying machinery is an interesting subject from an economic, as well as an engineering standpoint. In 1907 there were taken from the ranges adjacent to Lake Superior and transported to furnaces in the Pittsburg and Ohio district 42 000 000 tons of iron ore. Following the same route but in the opposite direction, there were mined in Pennsylvania, Ohio, and elsewhere 17 000 000 tons of anthracite and bituminous coal, and shipped to the Northwest, the vessels loading usually at the same ports at which they discharged their cargoes. The labor cost of transferring such great quantities of these materials between vessels and cars has become an important consideration, and in some respects the time spent in loading and unloading the vessels means more.

CARGO STEAMERS AND LOADING WHARVES ON GREAT LAKES

2 Efforts to secure economical handling have developed machinery combining mechanical simplicity with great capacity and economy, and have made possible the steamers of special design now engaged in this business, and the lowest freight rates known in the world. Many of the modern vessels engaged in this trade have a length of 570 ft., a beam of 58 ft., and a draught of 18 ft., and are provided with hatches spaced 12 ft. centers. When these hatches are removed the cargo is practically uncovered and can be unloaded, with little or no hand

To be presented at the Detroit Meeting (June 1908) of The American Society of Mechanical Engineers.

The professional papers contained in Proceedings are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present. They are issued to the members in confidence, and with the understanding that they are not to be published even in abstract, until after they have been presented at a meeting. All papers are subject to revision.

The Society as a body is not responsible for the statements of facts or opinions advanced in papers or discussions. C55.

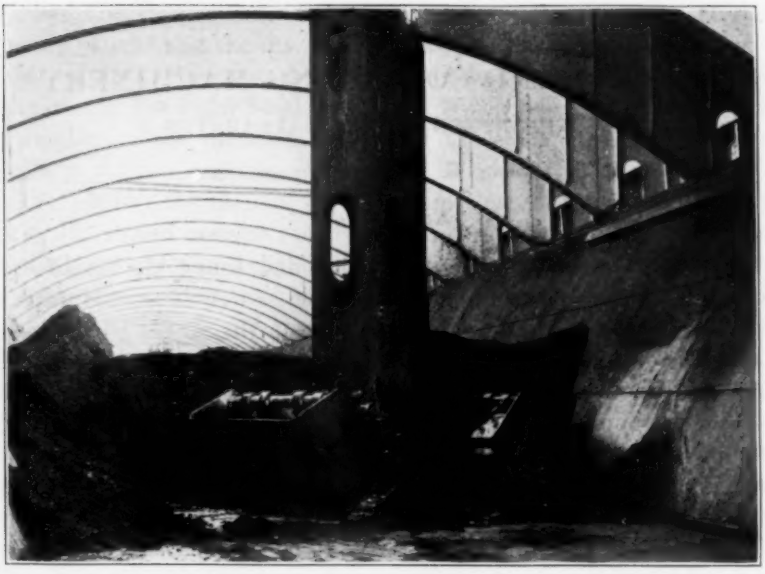


FIG. 1 BUCKET OF HULETT AUTOMATIC ORE UNLOADER IN HOLD OF A VESSEL

FIG. 2 HULETT AUTOMATIC ORE UNLOADER

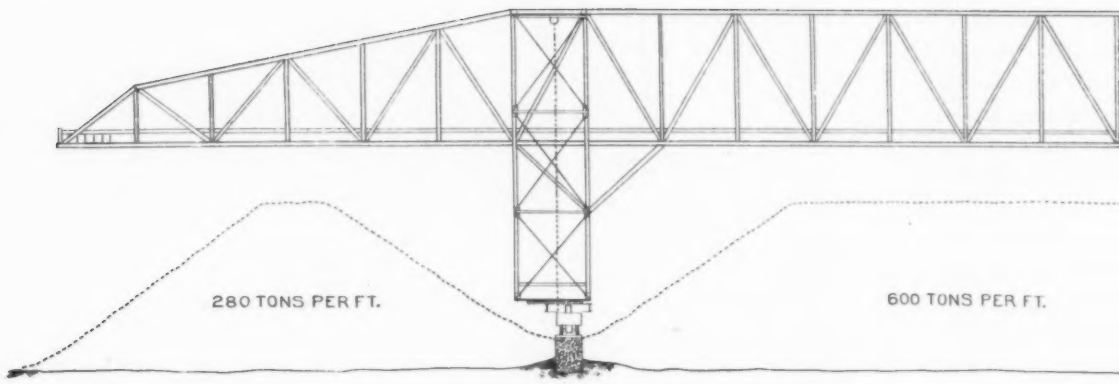
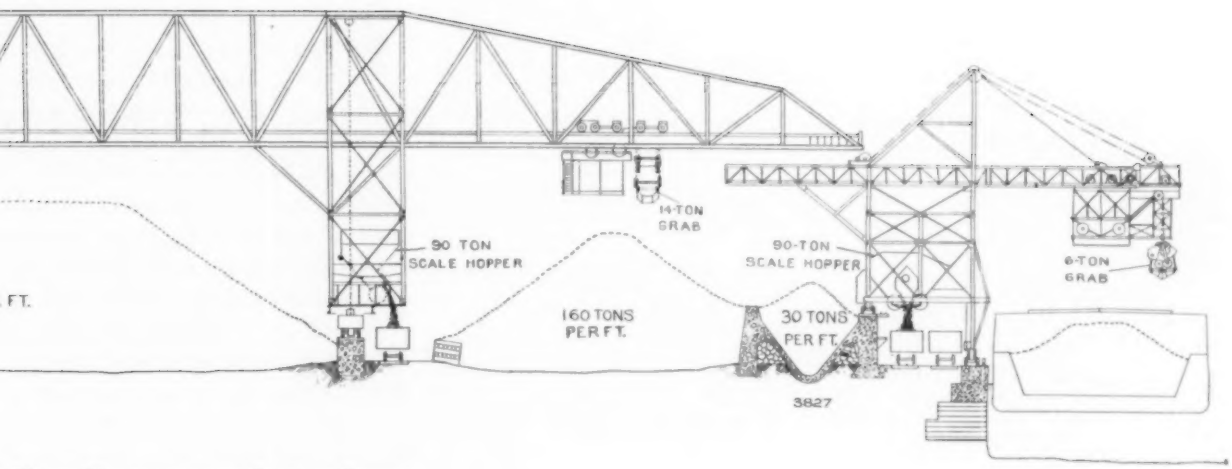


FIG. 3 HOOVER AND MASON U



D MASON UNLOADING AND STORAGE SYSTEM

labor being necessary for trimming. The ore coming in cars from the mines is shipped from about thirty-two large wharves at ports on Lake Superior and Lake Michigan. Some of these piers are 2000 ft. long, with tracks arranged so that four large steamers can take on cargo at once. The ore is run directly into the holds from the cars or storage pockets, and carried by gravity through chutes which are lowered into the hatches.

ORE UNLOADING MACHINERY ON GREAT LAKES

3 In unloading ore from lake vessels, on account of the difficulty and cost of shoveling by hand, three modern types of machinery for performing this work, practically without manual labor, have been installed. The first is the Hulett automatic ore unloader shown by Fig. 1. This machine operates a self-filling bucket of large capacity mounted at the end of a rotating vertical leg; the bucket having sufficient spread to reach more than half way from the center of one hatch to the center of another. It also travels lengthwise of the hatch to the sides of the boat, and, consequently, commands a large percentage of the cargo. The bucket is closed and removed from the hold under the control of an operator located in the lower end of the leg where he has an unobstructed view of the cargo and vessel. The bucket discharges its contents into a bucket-car for delivery to railroad cars located under the gantry of the machine for shipment to blast furnaces, or it may be drawn out to the end of the cantilever and dumped so as to form a pile to permit re-handling by buckets to storage pile.

4 Other types of machines used for this purpose are shown by Fig. 3, a Hoover & Mason unloading and storage plant, and Fig. 4, a Brown Hoisting Machinery Co.'s unloader and storage bridge. On these machines, the bucket, instead of being fixed at the end of a vertical leg, is rope-suspended from a hinged cantilever over the vessel, and is operated by a man-trolley provided with means for rotating it when in the hold, so as to more completely command the cargo, or to remove the bucket from the boat and deliver its contents either into cars under the gantry, or onto stock pile. From the latter it is handled by a similar bucket, but of larger capacity, mounted on a movable bridge tramway provided with double cantilevers, as shown by Fig. 5.

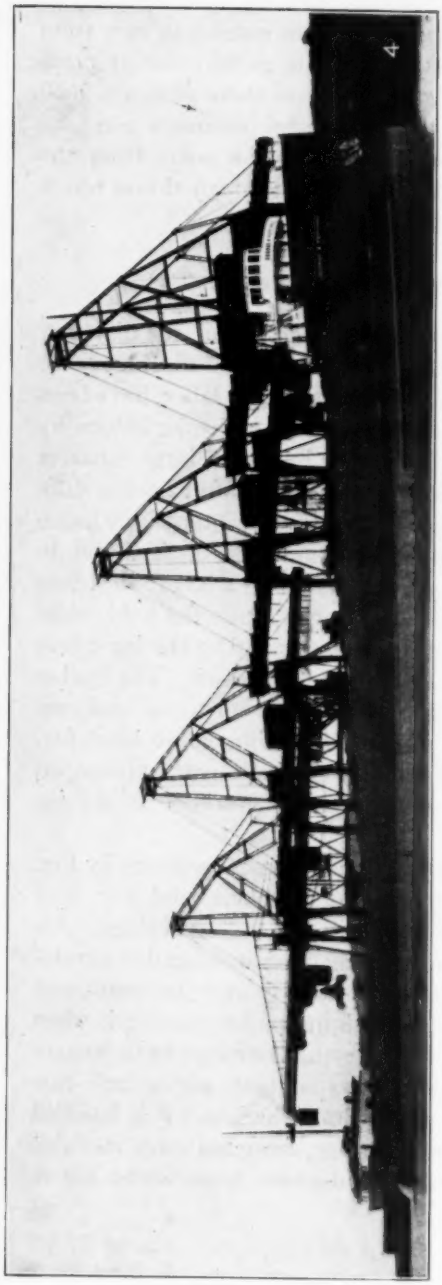


FIG. 4 BROWN HOISTING MACHINERY CO.'S UNLOADER

FIG. 5 ELECTRIC MAN-TROLLEY BRIDGE TRAMWAYS

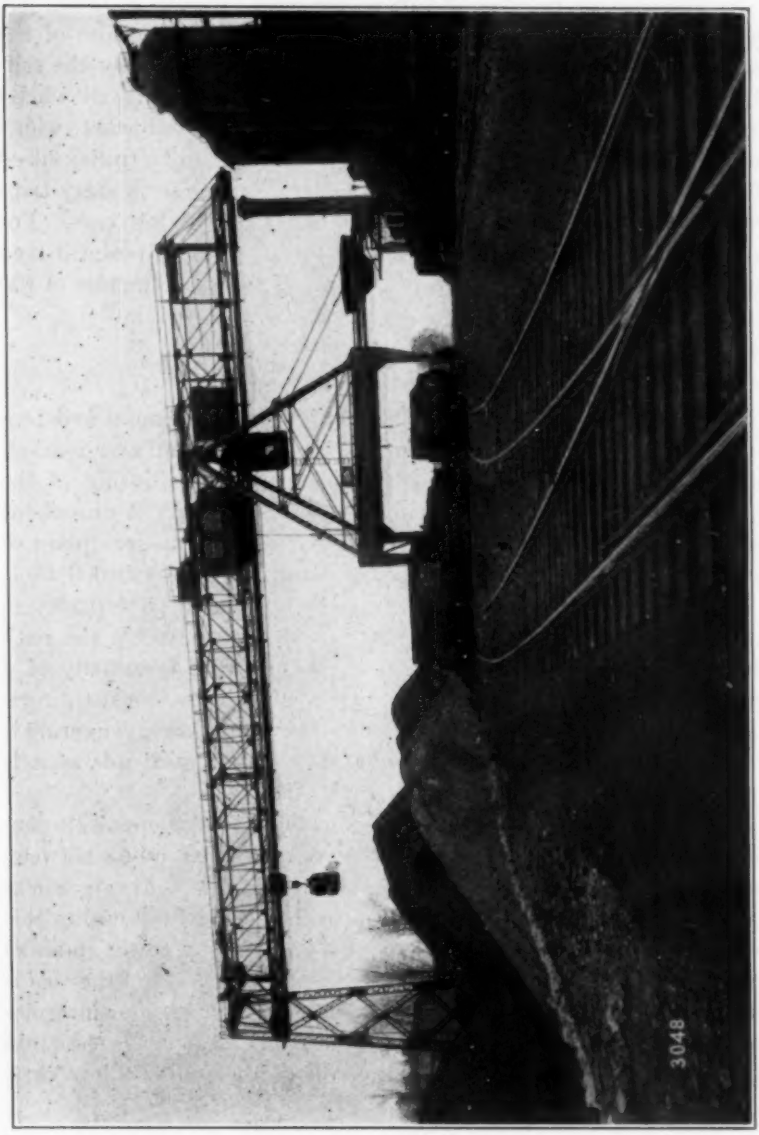


FIG. 6 ORE UNLOADER AT BLAST FURNACES

ORE STOCKING MACHINERY AT FURNACES

5 The iron ore received in cars at the blast furnaces is discharged by means of car dumping machines, or through the bottom of the cars into track hoppers, or taken directly from the cars by the self-filling bucket with which the machines are equipped, as shown by Fig. 6. This machine is electrically operated and its bucket, which holds 5 tons, has a hoisting speed of 300 ft. per min. and a trolley speed of 800 per min., and an average capacity for one hour, of sixty trips from track hopper to stock pile, or from stock pile back to cars. For moving the bridge back and forth over the stock yard, power-driven mechanism is provided to operate it along its tracks at the rate of 100 ft. per min.

ANTHRACITE COAL STORAGE MACHINERY

6 Anthracite coal, owing to the fluctuations in demand and production, is stored in large quantities between mine and market, making possible continuous, instead of spasmodic working of the mines, and also providing convenient bases of supply. A prominent installation is shown by Fig. 7, a general view of a modern plant of the "Dodge System." The immense quantity, over 480 000 tons, is divided into eight separate piles, each pile having a capacity in excess of 60 000 tons. The standard machine for storing the coal, which is received from the mines in cars, consists essentially of a chain and flight conveyor supported by a shear truss, constituting a trimming machine which piles the coal without breakage, delivering it upon the ground or at the ascending apex of a conical pile as it is formed.

7 The reloading of the coal is begun by a pivoted open-side conveyor which runs on circular ground-level tracks extending between and over the area to be covered by the piles. This conveyor works against the edge of the pile, as shown by Fig. 8, and follows up this receding edge as the coal is removed; it is operated by power and is so devised as to be fully under the control of one man. All of the coal is tributary to the reloading conveyors and is carried without intermediate transfer up the incline to a reloading tower (as shown in the background of Fig. 7), where it can be delivered either directly into cars, or screened and then delivered into cars.

8 In detail the "Dodge System" as usually applied to open air storage on leveled ground consists of two trimming machines and the pivoted ground conveyor which travels radially between them, form-

FIG. 7 ANTHRACITE COAL STORAGE PLANT—"DODGE SYSTEM"

ing one unit or group. A coal storage plant consists of a number of these groups, which may be of equal or varied capacities. The shear trusses are fixed to correspond with the angle of repose of the coal,—the front truss of each group, *i. e.*, the truss adjacent to the track-hopper or receiving-point, containing the conveyor. This conveyor runs in a trough having for a bottom a continuous steel ribbon about 12 in. wide, which is wound upon a drum at the foot

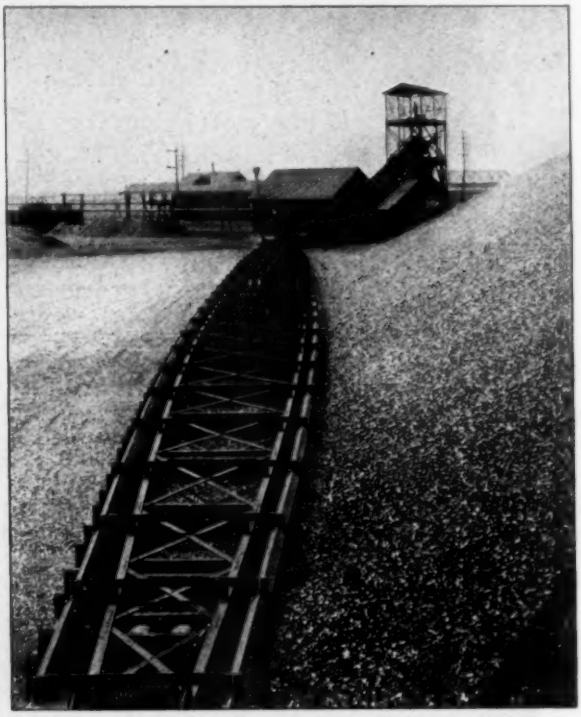


FIG. 8 PIVOTED OPEN SIDE CONVEYOR FOR RELOADING COAL

of the truss, and is paid out only as demanded by the formation of the pile; this feature provides a gentle discharge of the coal and prevents breakage.

9 Modifications of the standard "Dodge System" have been made to meet local conditions; hill-side storage has been increased by mounting the trimmer-conveyors on cantilever trusses, so as to fully command the storage area after the initial and comparatively small gravity capacity has been reached. Where a continuous pile of

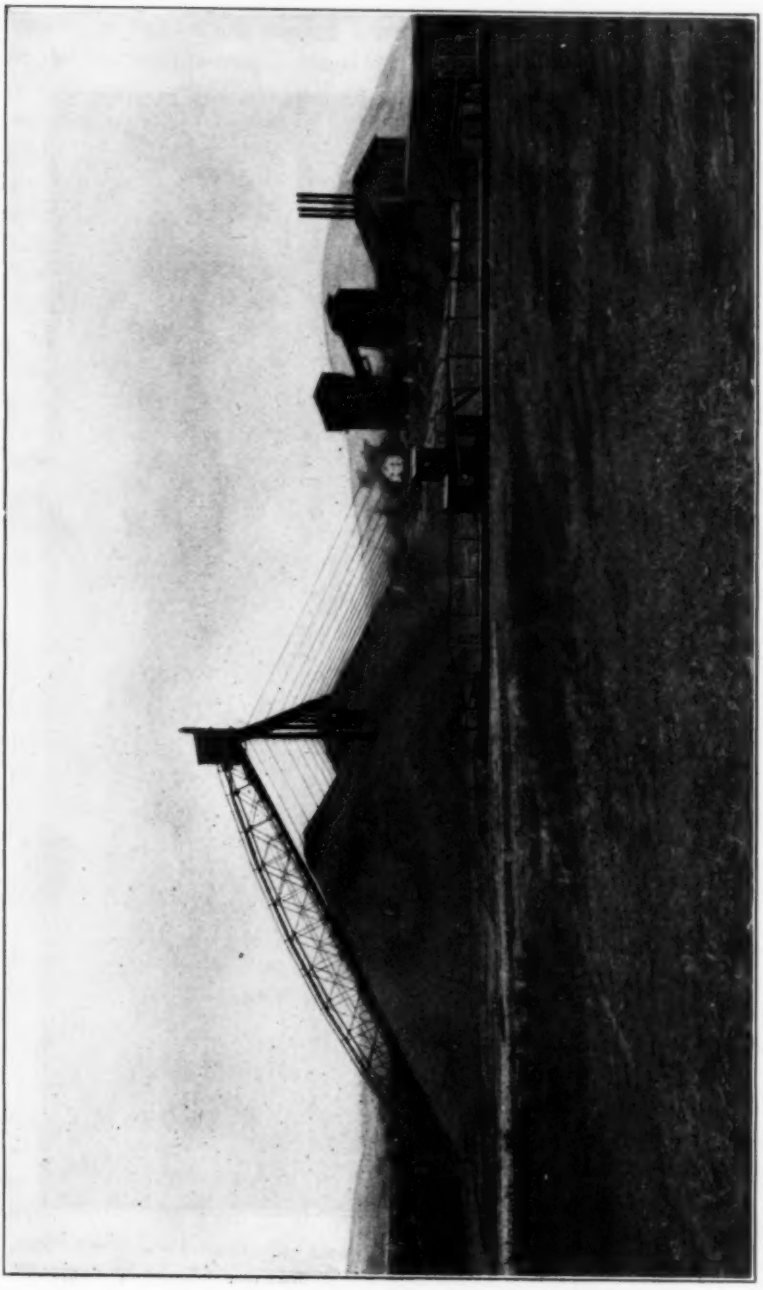


FIG. 9 PLANT WITH TRIMMER AND RELOADING MACHINE OF TRAVERSING TYPE

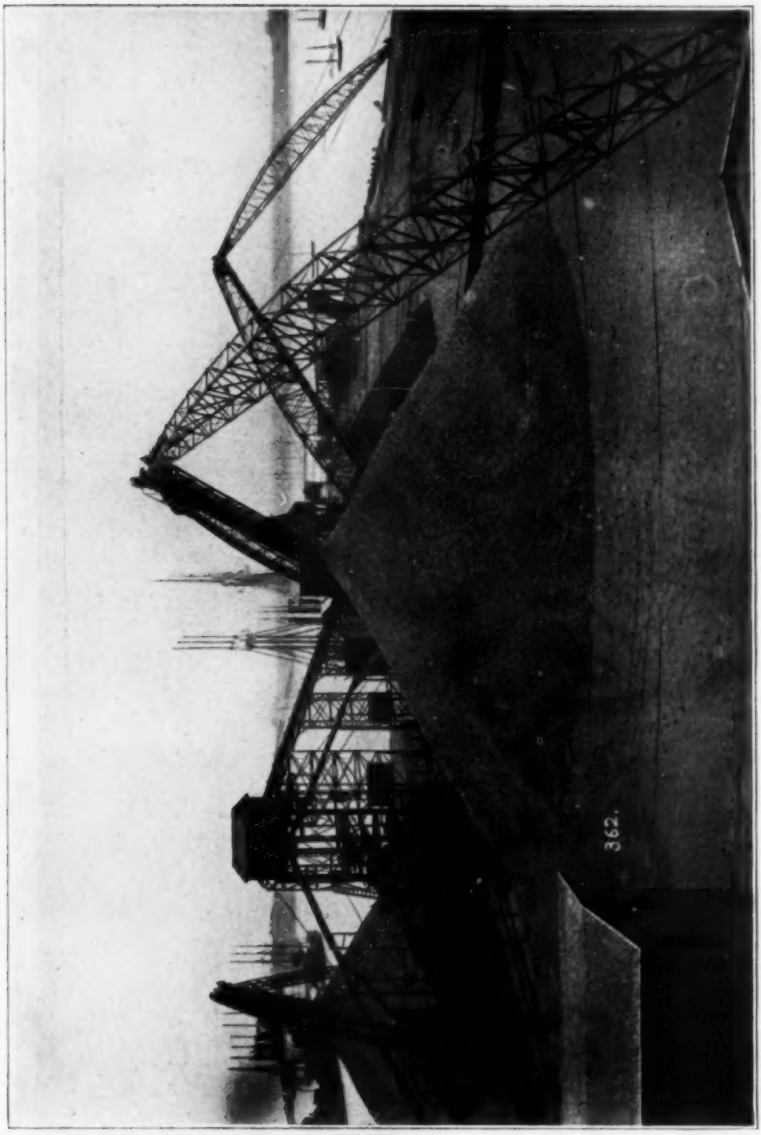


FIG. 10 ANTHRACITE HANDLING AND STORAGE MACHINERY SITUATED ON WATER FRONT—"DODGE SYSTEM"

maximum capacity is needed, a traveling trimmer is used, supported at the foot on a power-driven truck, and at the head on a column-supported track. Stocking out, or storing, is accomplished as in the standard group plant; the reloading machine being of the traversing, instead of pivotal type. In the plant shown by Fig. 9 two of these machines are employed—one on each side of the storage area—and deliver to flight conveyors running in and towards the middle of an underground tunnel which is laid parallel to the traverse of the trimmer. From these flight conveyors the coal is delivered to a bucket conveyor placed at right angles to them, which carries to a reloading tower for car delivery.

10 Application of the anthracite storage machinery covers successfully the requirements of water-front delivery. At the plant shown by Fig. 10 the coal is received altogether by boat and is unloaded by means of automatic buckets, which serve a conveyor of large capacity terminating in a central tower, from which chutes distribute to the trimmer conveyors. Reloading is similar to that of the inland storage plants.

COVERED ANTHRACITE STORAGE

11 Where climatic severity makes covering of the coal necessary the "Dodge System" has been found especially adapted to the conditions governing location and transportation facilities. A prominent installation of this kind employs a circular building with trussed dome-shaped roof. The coal is brought to the dock by boat, and unloaded by steeple tower hoist, from which it is spouted by gravity to the chute of the trimmer conveyor. The construction of the trimmer permits it to be mounted on one of the roof trusses of the building. The reloading from pile is effected by means of the pivotal reloader which commands the inner circumference of the building, and delivers through floor openings to a flighted chain conveyor running, horizontally in a tunnel, from position beneath the center of the pile to a point outside the building. From here it rises on an incline to the reloading tower from which its discharge is transferred through screening chutes to cars. No exterior bracing is required for these buildings, as they are strengthened against bursting pressure from the mass of coal by a continuous circular bulk-head, which is supported free of the floor by anchor bolts extending inwardly from the I-beam posts of the annular wall.

12 Another type of covered storage plant is shown by Fig. 11, in which the housed area is of rectangular form, the building being

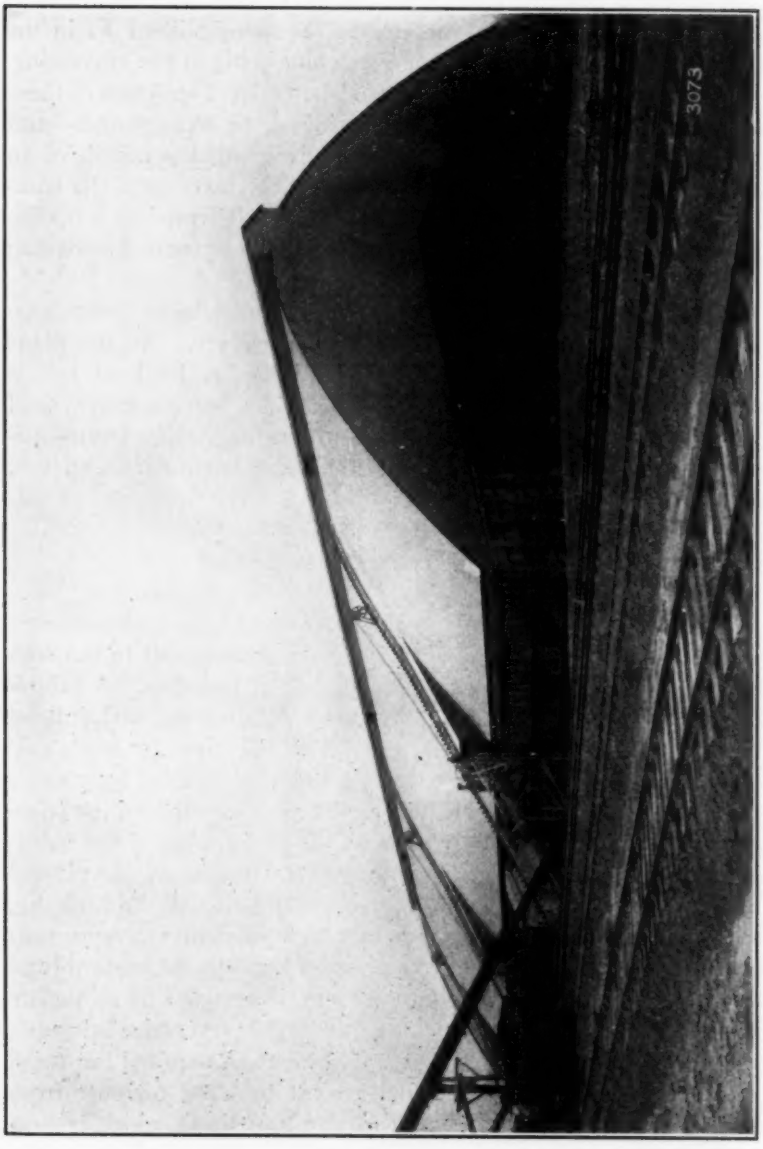


FIG. 11 TYPE OF COVERED STORAGE PLANT

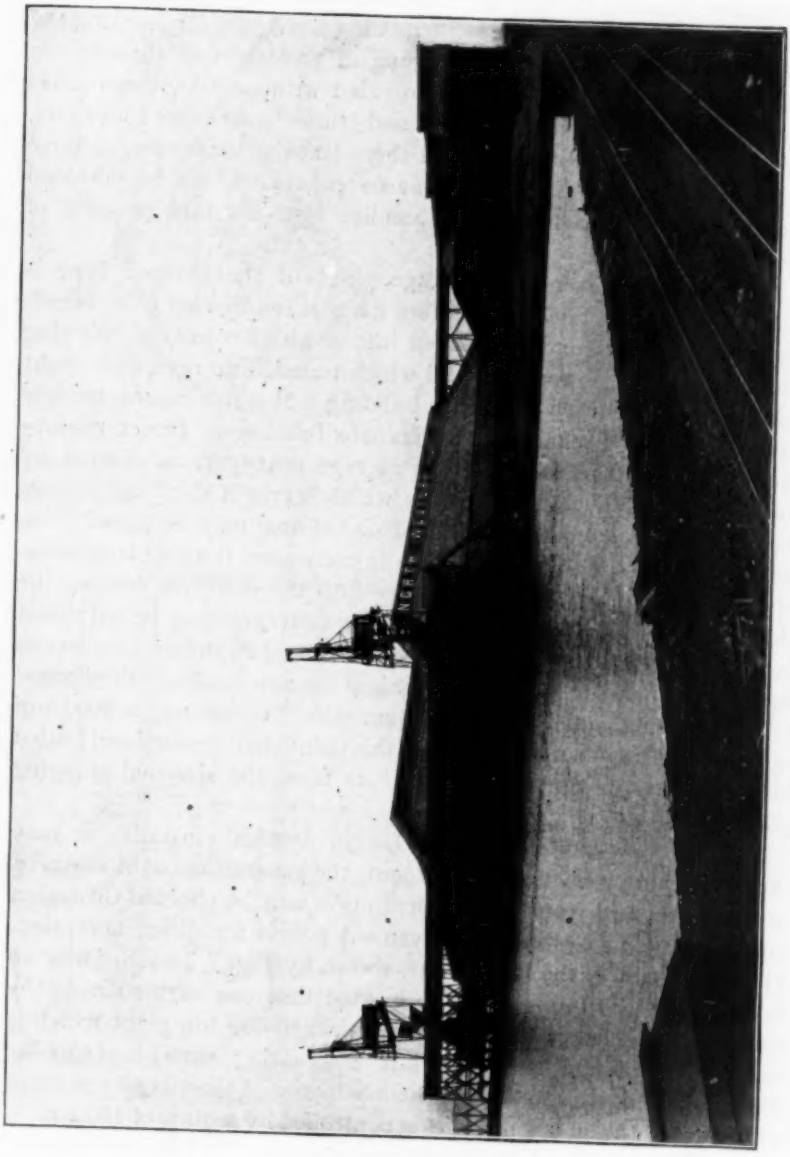


FIG. 12 WATER FRONT COVERED STORAGE PLANT

divided to store equal quantities of egg, stove, and nut coal, the aggregate capacity footing up to 100 000 tons. The equipment consists of three standard "Dodge" trimming conveyors for stocking the coal; three open-top carriers, running in underground tunnels, for reloading; three reloading towers provided with screens; three gravity-discharge transfer conveyors; and three screenings conveyors. The three trimmer conveyors and three transfer conveyors, or three reloading conveyors and three transfer conveyors, can be operated simultaneously. Each machine handles 1500 net tons per day of ten hours.

13 Another water-front storage plant of the covered type is illustrated by Fig. 12 and 13. Here the coal is unloaded from vessels by steeple towers, and discharged into a wharf conveyor, carrying on its upper and lower run, and which transfers to reversible flight conveyors for delivery to storage building. Movable ribbon troughs permit gradual discharge and eliminate breakage. Direct re-shipment from storage, or from the storage conveyors, is effected by another reversible flight conveyor which serves a shipping pocket. To reload from storage, the desired size of coal may be drawn from underneath the pile through chutes to conveyors running lengthwise of the building, and which discharge into the conveyor serving the shipping pocket. Coal tributary to this conveyor may be fed direct to it. From the shipping pocket coal is conveyed to box cars served by a Smith box car loader. Screenings are automatically discharged to a conveying and elevating system which commands a 3000 ton screenings storage building. From this point they are sized and loaded into box cars in the same manner as from the size-coal shipping pocket.

14 The power plant for a "Dodge System" installation may include steam or electrical equipment, the generating outfit comprising a central unit from which distribution may be effected through a piping or wiring system to convenient points for direct operation. The equipment of the large plant, shown by Fig. 7, includes four 16 in. by 20 in. 150 h.p. engines so located that one engine drives the machinery of each two-pile group. In a 240 000 ton plant which is nearing completion, two 225 h.p. alternating current, 440-volt, 25-cycle, 3-phase motors drive the machinery of the 60 000 ton piles, while that of the 30 000 ton piles is controlled by motors of 150 h.p.

15 The capacity of the plants erected under the "Dodge System" aggregates a total of about 5 000 000 tons. While official figures are not obtainable for publication, it is guaranteed that the labor cost of

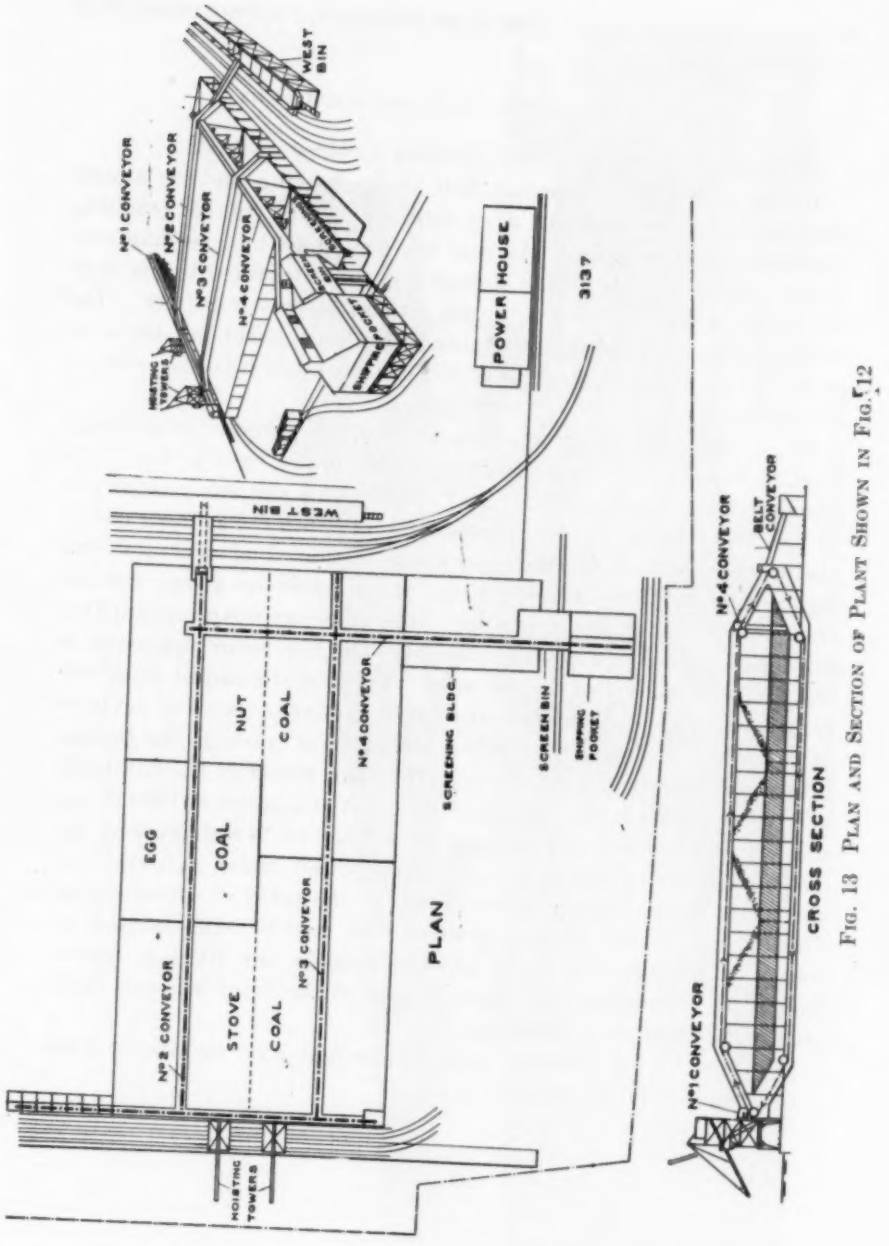


FIG. 13 PLAN AND SECTION OF PLANT SHOWN IN FIG. 12

either stocking out or reloading on an active plant will not exceed four cents per ton.

BITUMINOUS COAL STORAGE MACHINERY

Bituminous coal is generally handled by three methods.

16 (*a*) A Robins Conveying Belt Co.'s stocking and reclaiming machine, Fig. 14, consists of a lateral-traveling bridge tramway spanning the storage area, the coal being supplied by a feeding conveyor running parallel to the storage area, and delivered to the storage pile by a belt conveyor equipped with an automatic tripper. The coal is reclaimed by a counterweighted self-filling bucket and delivered to the longitudinal feeding conveyor for transmission to the point of consumption.

17 (*b*) Another type of machine used for this purpose is the Dodge Coal Storage Co. rotating bridge tramway shown by Fig. 15. This machine has a span of 280 ft., and commands a circular storage pile of 100 000 tons, the coal being piled 30 ft. in depth. The inner end of the bridge is pivoted and the outer end is supported on structural steel legs resting on power-driven trucks, which travel on a semi-circular track at the rate of 200 ft. per min. The tramway is equipped with a self-filling bucket of four tons capacity, and the entire operation of the bridge is controlled by one man. The coal is dumped from railroad cars into a track hopper pit located under the center of rotation of the bridge. The bucket, which travels on a track on the bridge, lifts the coal from this pit through the open center of the turntable at a speed of 300 ft. per min. and trolleys it at a speed of 1000 ft. per min. for discharge to the storage pile. The coal is reclaimed by the bucket delivered to a receiving hopper placed under its path, and carried by means of conveyors or cars to the point of consumption. The machine is electrically operated, the bucket being hoisted by means of one 200 h.p. motor and trolleyed by one 100 h.p. motor. Rotation is effected by the trucks located on the outer legs and operated by two motors of 30 h.p. each.

18 The cost of handling coal for the first nine months of 1906 with this machine was as follows:

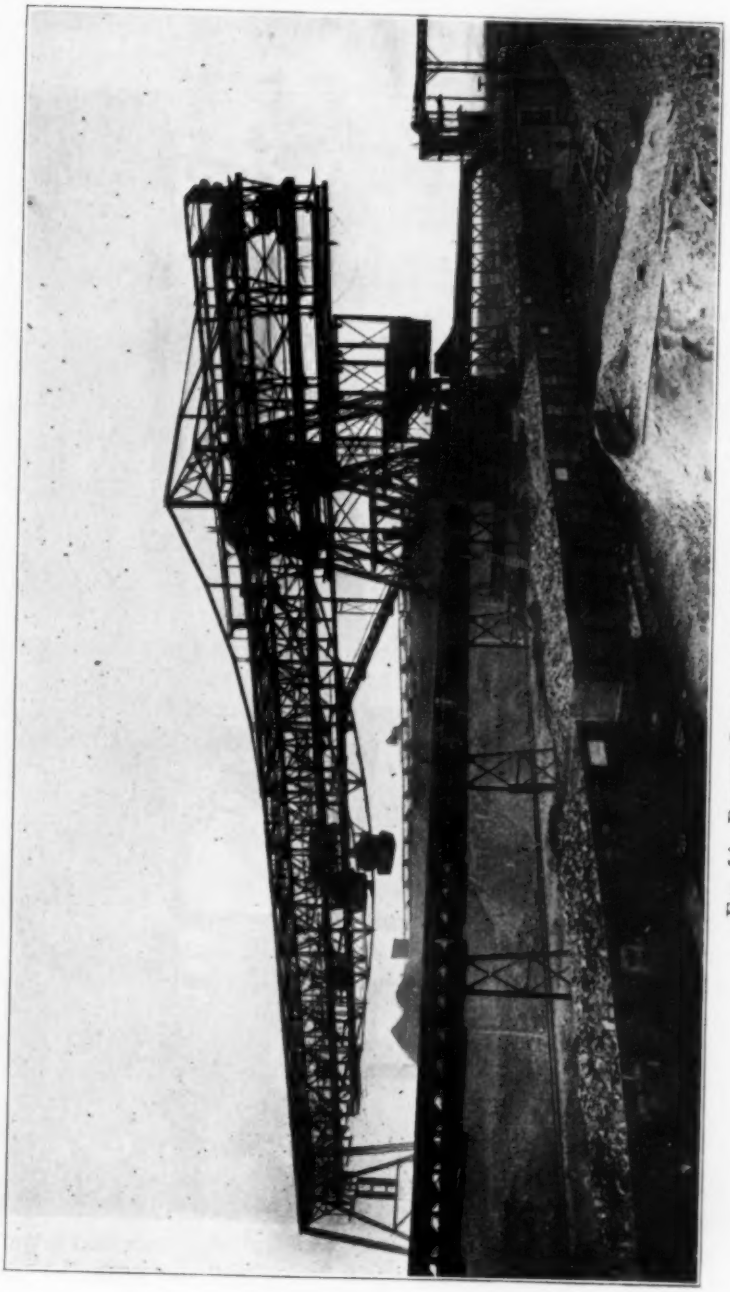


FIG. 14 ROBINS STOCKING AND RECLAIMING MACHINE

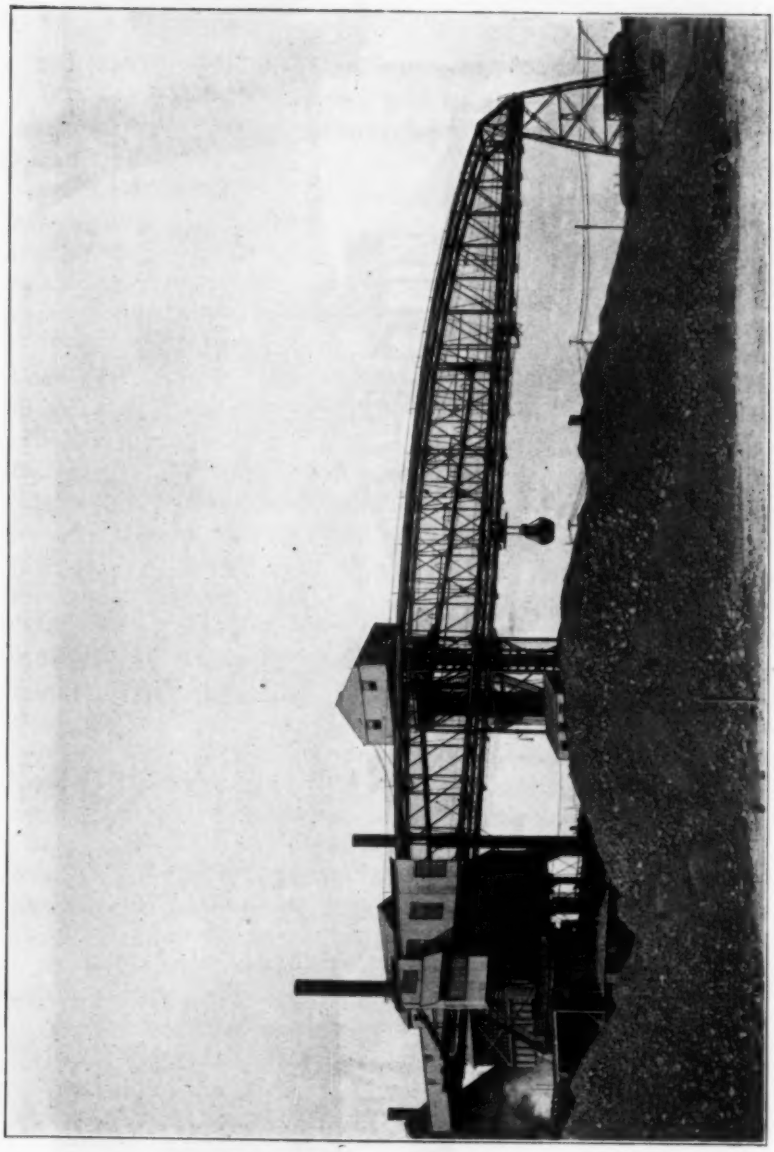


FIG. 15 COAL STORAGE ROTATING BRIDGE TRAMWAY

Month	Hours in operation	Tons	Renewals	
			Labor	Material
Jan.	100 at 43 cents	5 210	$43.59	$135.43
Feb.	80 at 43 cents	4 740	64.86	0.00
Mar.	100 at 43 cents	6 210	52.87	149.51
April	210 at 43 cents	13 800	35.83	35.36
May	130 at 43 cents	7 710	65.56	171.06
June	36 at 43 cents	1 710	55.75	0.00
July	204 at 43 cents	12 340	26.36	24.22
Aug.	148 at 43 cents	7 980	57.27	223.64
Sept.	71 at 43 cents	3 780	50.87	0.00

Summarized, this gives the following:

Labor cost, handling coal	$0.0073 per ton.
Labor cost for renewals	0.0069 " "
Cost of renewals in material	0.0116 " "
Total	0.0258 " "

19 (*c*) For storing from 6000 to 40 000 tons of coal a long-radius Dodge Coal Storage Co. locomotive crane is used. This machine runs on a circular track around a central track hopper into which the coal is dumped from railroad cars, as shown by Fig. 16. The coal is taken from this pit by a self-filling bucket and delivered to the storage pile, which when full assumes the outline shown in the plan. (See Fig. 17.) When reloading, the coal is taken from the pile by the bucket, and delivered into cars or carts.

STORAGE FOR LOCOMOTIVE COALING STATIONS

20 Railroads also employ this type of crane for handling and storing coal for their locomotive coaling stations. These machines are steam-operated, and are equipped with a 2-ton self-filling bucket operated at 80 ft. radius. The coal is taken from the track hoppers and delivered to storage, and from storage to a pocket equipped with chutes for coaling six locomotives simultaneously.

The cost of operating the plant referred to for the month of December, 1907, was as follows:

Total cost of labor for unloading cars, operating cranes, and switching service, also repairs, fuel, and supplies,	$451.96
Total tons of coal in storage on first day of month	38 717
Tons of coal stored during the month	725
Cost to handle per ton	$0.0529

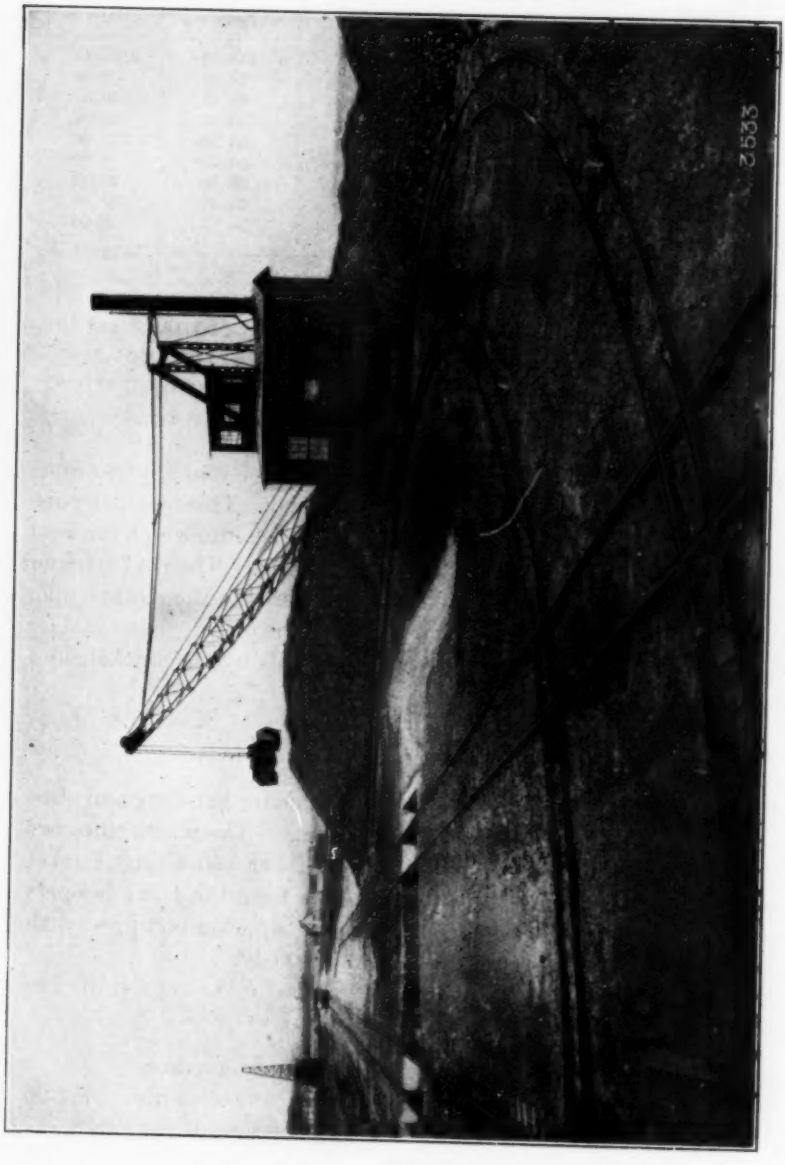


FIG. 16 COAL STORAGE LOCOMOTIVE CRANE

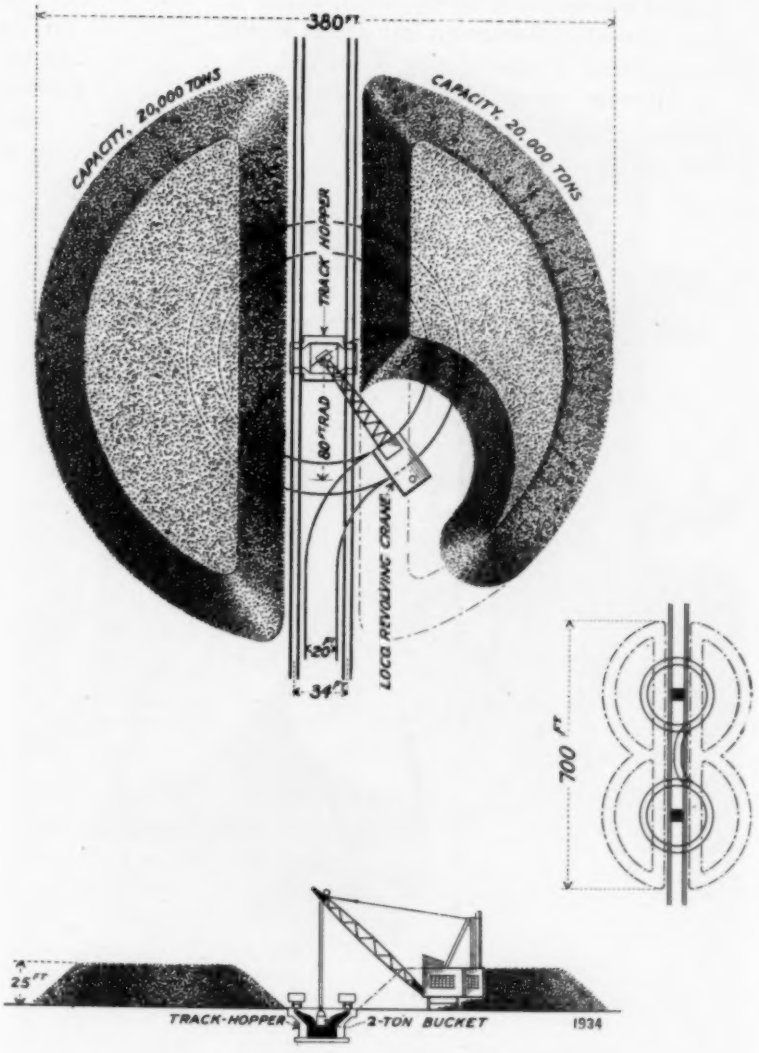


FIG. 17 DIAGRAM SHOWING AREA SERVED BY LOCOMOTIVE CRANE

Tons of coal delivered to engines, ...9624
Cost per ton to handle, ...$0.0429
Tons of coal reloaded for shipment, ...none
Tons of coal in storage on last day of month, ...35 574
Tons of coal handled during the month, ...10 349
Average cost per ton to handle, ...$0.0437
Number of hours operated, ...210
Tons of coal handled per hour, ...49.28

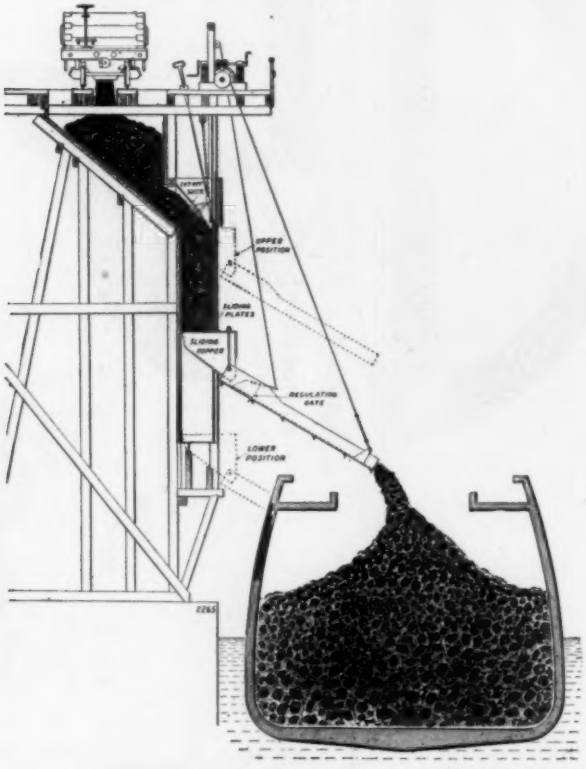


FIG. 18 ADJUSTABLE CHUTE FOR LOADING VESSELS

MACHINERY FOR LOADING COAL INTO VESSELS

21 On the Atlantic seaboard bituminous and anthracite coal is loaded in a large number of instances through the same type of pocket as that used for loading iron ore at Lake Superior ports, except that special devices, as shown by Fig. 18, are provided for reducing the breakage of coal between the car and the vessel. The

FIG. 19 CAR UNLOADING MACHINE

coal coming from the Eastern and Middle States in cars to shipping ports on Lake Erie is delivered to vessels by car unloading machines similar in design to that shown by Fig. 19. This machine is arranged to take cars of any size or capacity found in the trade, elevate, overturn, and deliver the contents through a telescopic chute into the hold of the vessel, and return the cars to the railroad system.

Maximum number of cars handled in one hour, 32.
" " " tons " " " " 1062.
Best record of loading vessel "Zenith City," loaded 130 cars, or 4240 tons, in 4½ hours. Average 29 cars, or 942 tons per hour.

MACHINERY FOR UNLOADING COAL FROM VESSELS

22 The coal on arrival at the upper lake ports is unloaded in a variety of ways, depending upon the character of the coal, the purpose for which it is intended, and the local conditions. A typical plant constructed by The Mead-Morrison Mfg. Co. is shown by Fig. 20. This plant consists of a rectangular storage wharf, on the water side of which, traveling on an elevated trestle, are three unloading machines equipped with self-filling buckets. Coal is unloaded by these machines and automatically delivered to a system of elevated cable cars running under the unloading towers and over continuous shipping pockets located on the center line of the property; or, if the coal is intended for storage, they are diverted to a traveling bridge and discharged onto the storage area. To reload the coal a shovel-bucket, with which the traveling bridge is equipped, is used to deliver directly into the pockets or to the cable cars for discharge along the line of the pockets.

23 Another type—the Dodge Coal Storage plant shown by Fig. 21. This plant is designed to avoid breakage as much as possible, and consists of three traversing bridge tramways commanding a storage of 250 000 tons of bituminous coal. The bridges are supplemented by two revolving locomotive cranes, two movable screening towers, and two box car loaders. The coal is unloaded from vessels by self-filling buckets of 3-tons capacity, and is delivered directly to storage, or through reloading hoppers, on front tower of tramways to cars for reshipment. Transfer from storage to cars is accomplished by similar bucket delivery to the reloading hoppers.

24 When size-coal shipments are desired, coal is taken from vessels or storage by bridge tramway or crane to the movable screening towers,

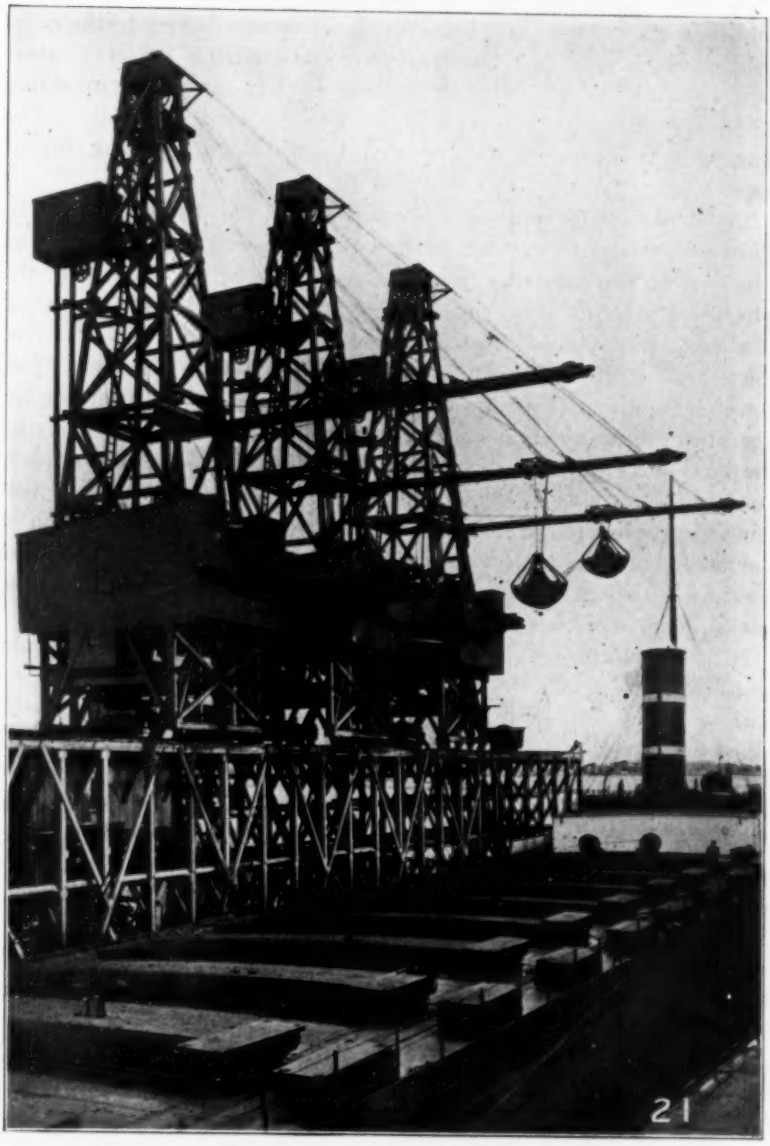


FIG. 20 MACHINERY FOR UNLOADING COAL FROM VESSELS

from which it is delivered to box cars alongside. Slack coal screened from size-coal shipments is automatically discharged into cars, or conveyed to slack storage, from which the cranes deliver to the movable screening towers for box car delivery as needed. Delivery to box cars, as noted, is facilitated in all cases by box-car loading machines of the Ottumwa type, operated by 100 h.p. motors. All of the machinery is controlled and operated by means of alternating current apparatus.

25 A novel distributing system delivers the 3-phase, 440-volt, 25-cycle alternating current by means of a series of contact posts, which in no way obstruct free passage of men or of material on the wharf. The bridge tramways have a total length of 506 ft., composed of a main span of 295 ft., an adjustable boom extension of 75 ft. over the vessel, and a rear cantilever extension of 136 ft. The electrical equipment of each tramway consists of one 225 h.p. motor for operating the hoisting machine, and two 75 h.p. motors for trolleying the bucket and moving the bridge along the dock. The complete operation of each bridge is controlled by one man from either of two houses—one located at front of bridge and nearly over the hatch of the vessel, and the other adjacent to the rear tower. In this way the operator's view is unobstructed whether working at the front or the back of the wharf.

26 A comprehensive description of the screening towers would be to liken them to traveling mine tipples. Each tower is equipped with a 30-ton hopper for receiving run-of-mine coal from the self-filling buckets on the tramways or cranes. The hoppers are provided with standard screen bars, the spacing of which can be changed at will. An elevator and conveyor carry the screenings across the screening-tower bridge and deposit them on screening pile at the back end of the wharf. The screened coal is loaded into box cars by the electrically-operated box car loaders referred to previously. The cranes have a gage of 10 ft., and a maximum radius—from the center of rotation to the center of the bucket—of 45 ft. The traveling speed of each crane is 300 ft. per min., driven by 75 h.p. motor, and the hoisting speed, 250 ft. per min.

27 This plant has the following record of performance: During the month of October 1907, the three bridge tramways unloaded from vessels and discharged 85 266 tons in 718 hours. In handling this tonnage the buckets made 34 933 trips, one-half the coal being lowered very carefully to the wharf. A round trip from the center of the vessel over a traveled distance of 270 ft. and return was made in 45

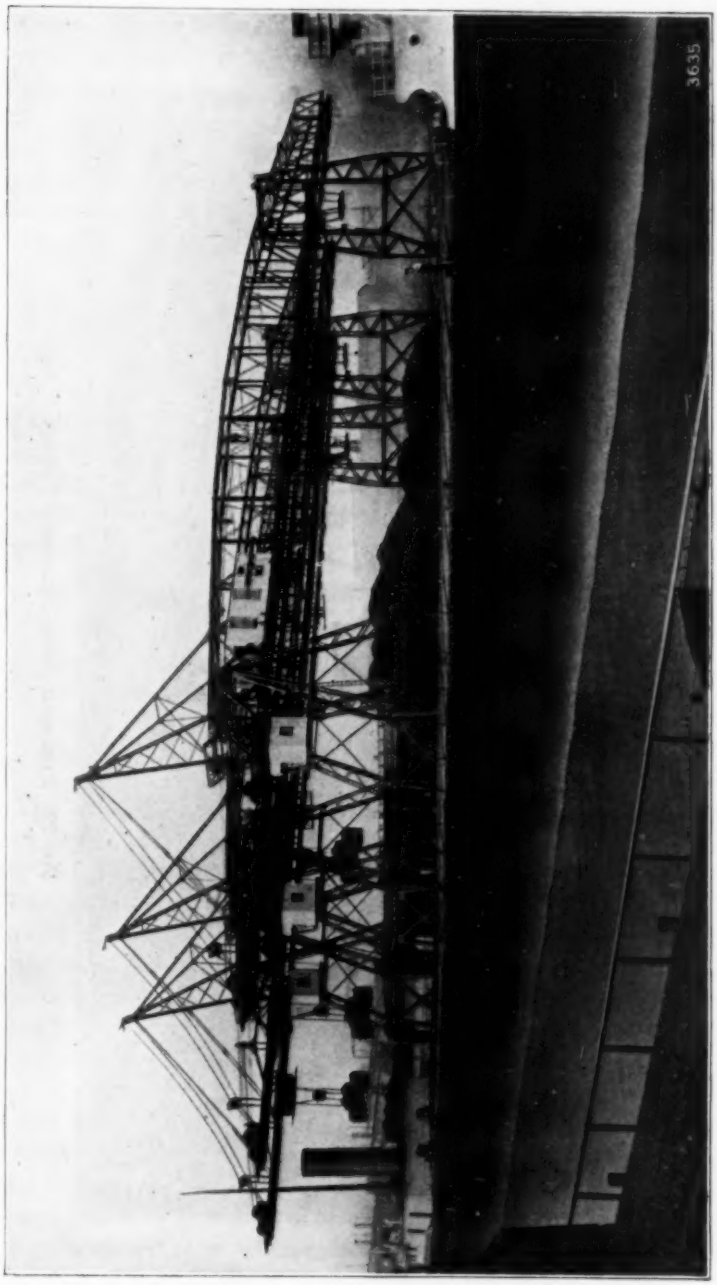


FIG. 21 BRIDGE TRAMWAY TYPE OF BITUMINOUS COAL STORAGE PLANT

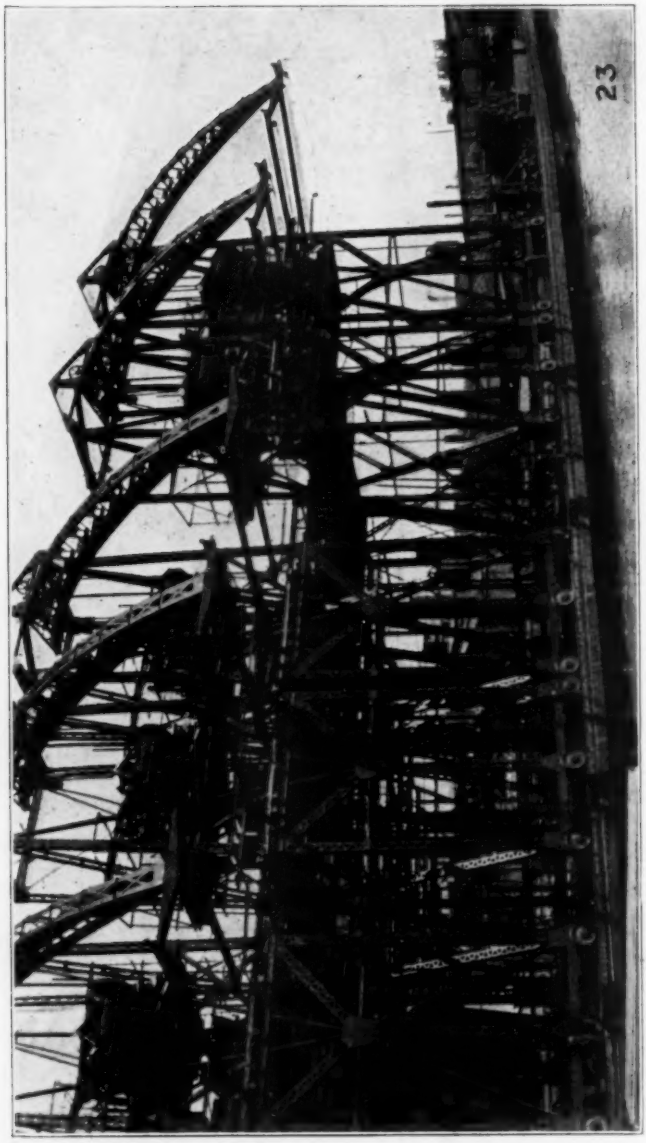


FIG. 22 PARABOLIC BOOM UNLOADING TOWERS

seconds. In one hour one bridge made 100 round trips from vessel to front of storage pile. The three bridges made 822 trips in 693 minutes, and disposed of a cargo of 10 500 tons in 26 hours.

28 Another type of coal unloader, as shown by Fig. 22, is made by the C. W. Hunt Co. This plant has five unloading towers fitted with parabolic booms which handle two-ton shovels. There are 27 automatic railway tracks to carry the coal from the storage sheds.

VARIATIONS IN DESIGN—FREIGHT HANDLING

29 Machines similar to those in use for unloading ore at Lake Erie ports are also suitable for handling general merchandise between cars and ships. The Dodge Coal Storage Co., direct unloading machine shown by Fig. 23 has two independent tracks, one of which is equipped with hoisting mechanism, for handling general merchandise, and the other with a self-filling bucket for handling bulk material. This machine is electrically-operated by means of alternating current.

The hoisting speed of a 10-ton load is	150	ft.	per	min.
" " " " 5-ton " "	300	"	"	"
The hoisting speed of 1-ton clam-shell bucket is	300	"	"	"
The trolleying speed of any load is	500	"	"	"
The traversing speed of unloader is	50	"	"	"

The control of the motors is such that any load from an empty hanging-block to the maximum load of ten tons can be operated at any required speed.

30 Fig. 24 shows a man-trolley similar to those used for unloading iron ore from vessels, the construction of the trolley being such that it passes freely around curves and over switches. These machines are used for handling materials at blast furnaces, and freight in large industrial plants. They may have a hoisting speed of 150 ft. per min., and a trolley speed of 1000 ft. per min. The man-trolley type of machine also operates on cableways of long span. The towers of the cableway are inclined to the horizontal, and provided with counterweights. The self-filling bucket, used in all cases where it is desirable to handle the material with the least possible hand labor, has been applied to traveling cableways.

31 Another type of apparatus for handling and transporting materials of various kinds is the familiar suspended cableway. The

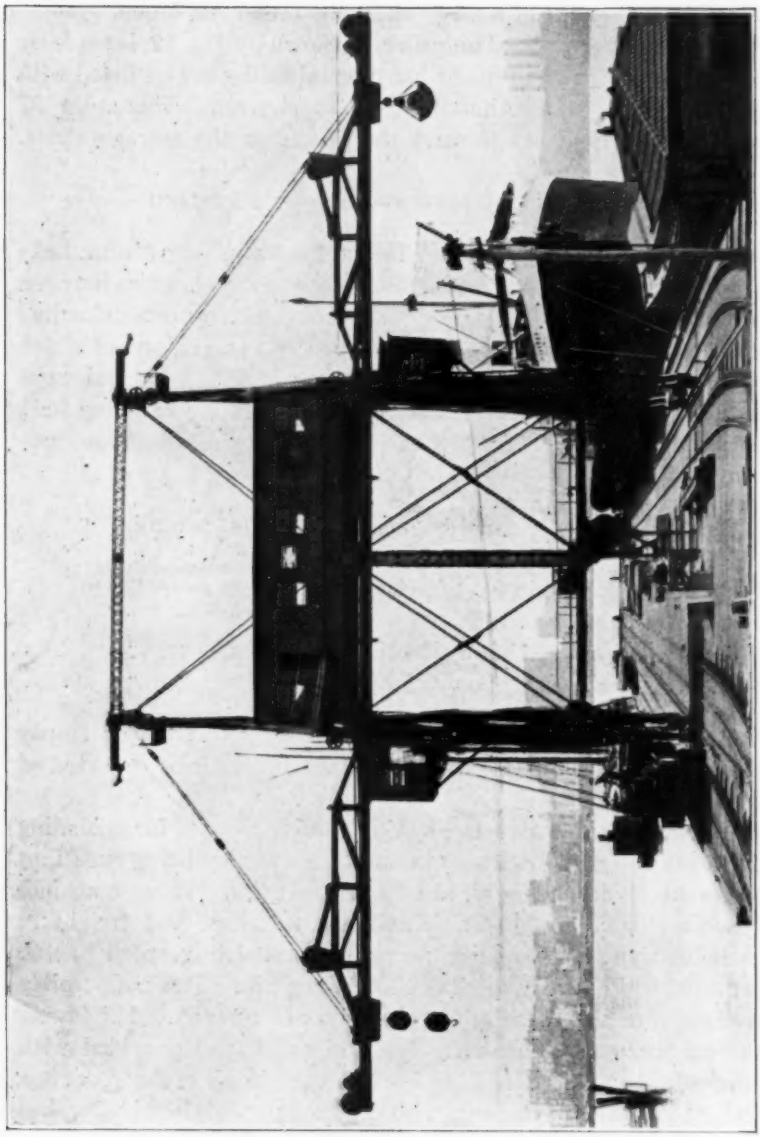


FIG. 23 DIRECT UNLOADER FOR HANDLING FREIGHT

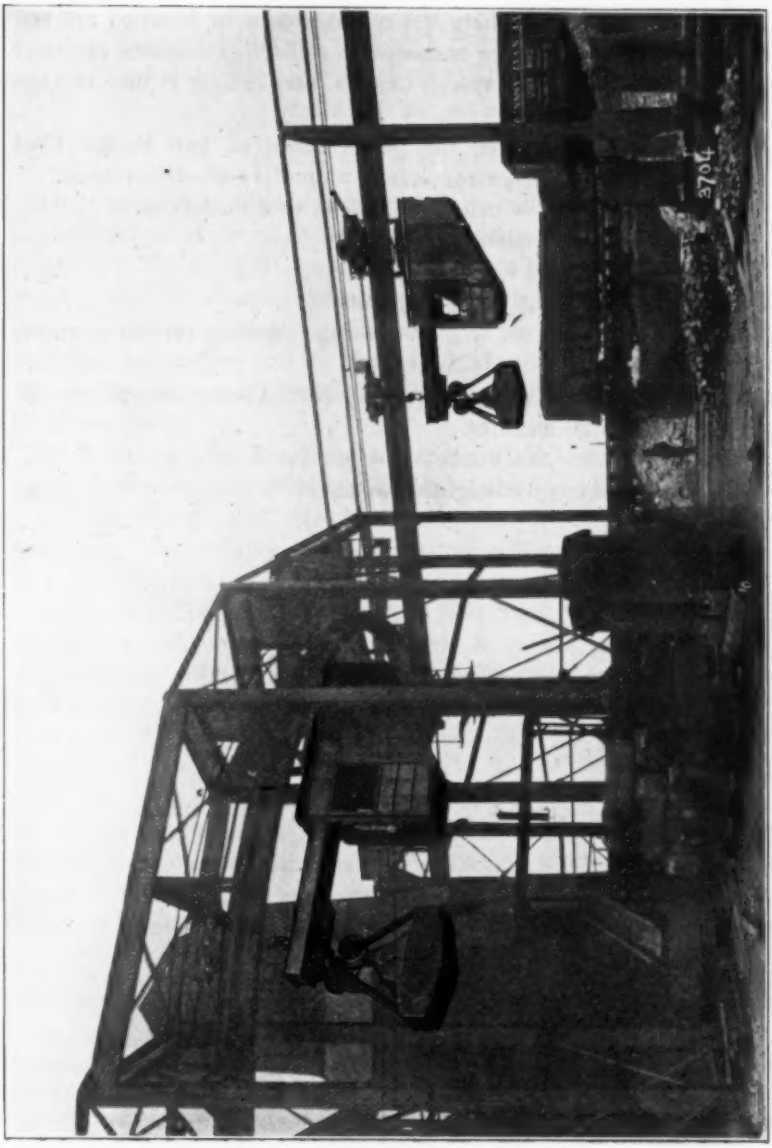


FIG. 24 MAN-TROLLEY FOR HANDLING FREIGHT

use of suspended cables for supporting the bucket makes it possible to construct machines of long span economically.

32 For installations where the quantities to be handled are not great, revolving locomotive cranes with self-filling buckets are used to take the material from vessels or cars, and deliver it into storage or cars.

33 The following gives the performance of two Dodge Coal Storage Co., standard-gage revolving locomotive electric cranes:

Material handled—crushed rock, ¾ in. to 2 in. mixed.

Bucket, 1 cu. yd., clam-shell.

Radius of crane, 35 ft.

Size of motor, 50 h.p., d.c., 500 volts.

Crane No. 1, from car to pile: Average capacity for ten minutes, 16 buckets.

Crane No. 2, car to street railway car: Average capacity:—20 buckets in 20 minutes.

Maximum rate—two buckets in one minute.

Buckets filled to seven-eighths capacity.

THE BELT CONVEYOR

By C. Kemble Baldwin, Chicago

Member of the Society

EARLY HISTORY

The transactions of this Society contain but one paper treating of the handling of material by belt conveyors, this one being contributed in 1885 by Mr. T. W. Hugo upon "Belts as Grain Conveyors." Mr. Hugo closes his paper as follows: "Enough has been said to show that it is a satisfactory method of handling grain, and not grain alone, but there are various articles that could be expeditiously and cheaply handled by this plan, or with modifications of it, to suit the articles to be handled."

2 Although little has been written on the subject, the prediction made 23 years ago has been realized, and today millions of tons of ore, stone, earth, coal, etc., are being successfully moved on belt conveyors; and this type of conveyor has firmly established itself in a field of its own.

3 In 1890 Thomas Robins, Jr., of New York, then engaged in the manufacture of rubber goods, visited the Edison Mines in New Jersey, where he saw rubber belts used for handling iron ore in the concentrating plant; and while they handled enormous quantities of ore with very little power, the belts, the best they could buy, lasted but a few months.

4 Mr. Robins subsequently conducted a long series of experiments to determine the proper belt construction, and the best compounds of rubber to withstand the abrasion of the material carried. Small rubber samples, each mixed differently, were exposed to the action of a powerful sand blast for the same length of time, each sample

To be presented at the Detroit Meeting (June 1908) of The American Society of Mechanical Engineers.

The professional papers contained in Proceedings are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present. They are issued to the members in confidence, and with the understanding that they are not to be published even in abstract, until after they have been presented at a meeting. All papers are subject to revision.

The Society as a body is not responsible for the statements of facts or opinions advanced in papers or discussions. C55.

being carefully weighed before and after the test in order to note the loss in weight. Test samples were also nailed to boards and placed in streams of falling ore in such position that the ore was immediately deflected, the samples being weighed before and after each test.

5 These tests, which extended over a period of nearly two years, showed that certain adulterants could be used in sufficient quantities to bring the cost of the belts to a marketable figure and still retain their abrasion resisting qualities. Belts made in 1892 from these compounds were for over four years under exactly the same conditions which had destroyed the former belts in three months' time. In 1896 Mr. Robins read a paper before the American Institute of Mining Engineers in which he fully explained the belt conveyor of that day and outlined his experiments.

6 The oldest type of conveyor consisted of a belt dragging along in a wooden trough and passing over flat faced end pulleys as in Fig. 1. The belts were of single ply canvas, or were of the ordinary type of rubber or stitched canvas belts. These crude home made affairs, while they did the work, wore out quickly, the cost of belt renewal being very high.

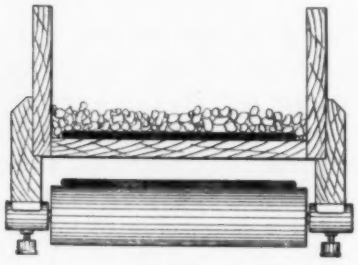


FIG. 1

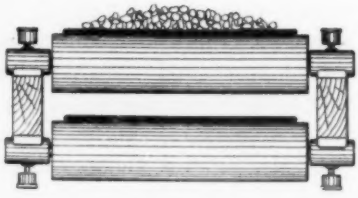


FIG. 2

FLAT FACED ROLLERS FOR BELT CONVEYOR

7 Flat wooden rollers, Fig. 2, were then substituted for the trough and the belts made wider to keep the material from jarring off when passing over the rollers. In many cases skirt boards were put the entire length of the conveyor to keep the material from rolling off, as in Fig. 3.

8 Naturally the belt would sag between the rollers, resulting in the material catching between the belt and skirt board at the rollers, which soon cut strips off the edges of the belt, and the skirt boards were arranged so they could be moved in as the belt became narrower.

9 The next and most natural development was to turn up the edges of the belt, Fig. 4, forming a trough which not only kept the material from rolling off, but prevented the belt from sagging between the supporting rollers. The wooden spool was made either in one or three pieces. Fig. 5 shows the concave roller made variously, in one piece, or cut into sections as indicated below, in order to reduce the slip on the under cover of the belt.

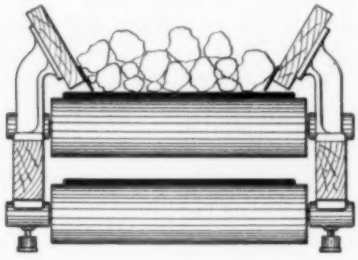


FIG. 3 BELT CONVEYOR WITH SKIRT BOARDS

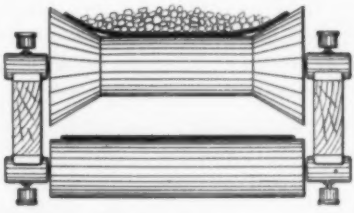


FIG. 4 WOODEN SPOOL TO CURVE THE BELT

10 In the case of both the spool and the concave roller this slip, due to the different diameters, while not serious on a grain conveyor where the belt presses lightly against the rollers, is a serious matter when handling the heavier materials, as the slip soon destroys the under cover of the belt.

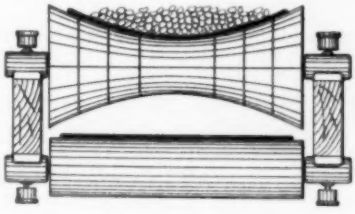


FIG. 5 CONCAVE ROLLER

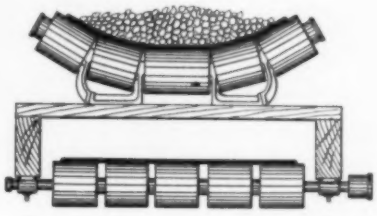


FIG. 6 IDLER FOR WIDE BELTS

11 A belt running at 400 ft. per minute 8 hours per day and 300 days per year, will travel during the year 57 600 000 ft. Taking one section of the roller in Fig. 5 with small diameter of 8 in. and large diameter of 12 in., assume that the section will turn at the speed of the mean diameter of 10 in. It will, during the year, make about 22 000-000 revolutions and with a slip of 6 in. per revolution, there will be a total slip of about 2000 miles per year. Results of actual practice

prove how destructive this is and stress is laid on the faults of this form of construction because several patents have been issued recently on carrier pulleys of this general type.

12 All of the forms described above are still used to a very limited extent, but the idler used almost universally today consists of a series of small pulleys of equal diameter arranged in the same or different planes, as in Fig. 6 and 7, which will produce no wear due to slip.

13 The troughing idlers should be spaced as follows, depending upon the weight of the material carried: On 12-in. to 16-in. belts, 4½ ft. to 5 ft. apart; 18-in. to 22-in., 4 ft. to 4½ ft.; 24 in. to 30 in., 3½ ft. to 4 ft.; 32 in. to 36 in., 3 ft. to 3½ ft.

14 Fig. 8 is a view of a 36 in. conveyor 670 ft. from center to center before the belt was put on. This conveyor has been in service over three years and has a capacity of 500 to 600 tons per hour.

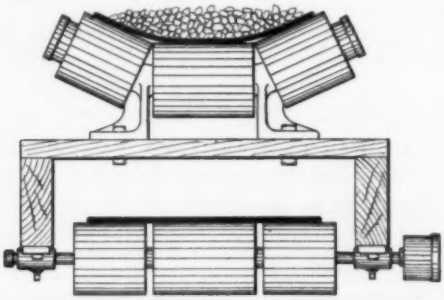


FIG. 7 IDLER FOR BELTS NOT EXCEEDING 26 IN. IN WIDTH

15 The lubrication of the idlers is an important matter, particularly where rubber belts are used, as oil or grease soon causes the rubber to deteriorate. Oil should not be used as it leaks out when the conveyor is not running and soon coats the faces of the pulleys and the belt. As conveyors usually work in dirty places, it is impossible to keep the oil wells clean and grease lubrication through hollow shafts is generally used. Such bearings are practically dust proof, any foreign matter being carried out by the grease and the small ring of grease which forms on the hubs of the pulleys acts as a most efficient dust collar. Grease lubrication without question increases the power consumed, but the great advantage of clean bearings, coupled with the low power requirements of the belt conveyor, has resulted in the general adoption of this method of lubrication.

16 The return belt is always carried on straight idlers consisting either of a number of small pulleys turning on a hollow shaft with grease cup on one end, or of small pulleys keyed to a solid shaft turning in pillow blocks. They should be spaced from 8 ft. to 12 ft. apart, according to the weight of the belt.

BELTS

17 Belts made of a great variety of substances have been used on conveyors and many tales of wonder have been told of the performances of some of them. A careful research, however, shows little

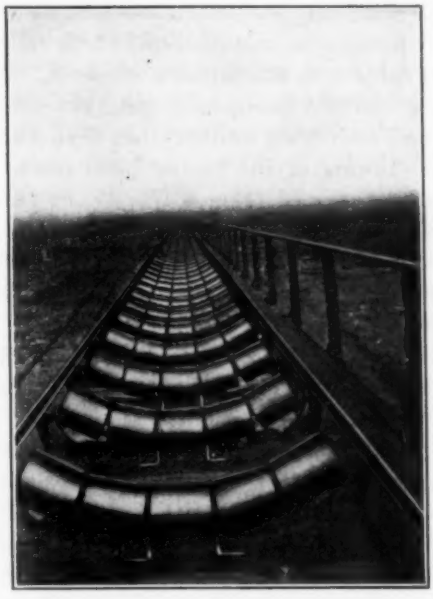


FIG. 8 36-INCH CONVEYOR BEFORE BELT WAS PUT ON

that is really new or important has been added to the art, although vast improvements have been made in the older types.

18 Stitched canvas and woven cotton belts are used to some extent, but generally their service is not satisfactory, mainly because it is impossible to water proof them thoroughly, Belts of this class are usually filled with oil, paraffin, or other such substance, the outside being coated with some water proof paint. When new, they are fairly flexible, but soon become so stiff that they will not trough

properly, and it is difficult to make them run true and straight. They are sensitive to atmospheric changes, requiring constant adjustment of the take-ups to keep them at proper driving tension. In one case under observation a 24-in., 5-ply canvas belt on a conveyor 400 ft. centers was handling crushed stone when the heat of the sun caused the belt to stretch and slip on the drive pulley. The take-ups were adjusted and the conveyor was again started. During the noon hour there was a shower of rain, causing the belt to shrink and as it was already tight, the tail structure of the conveyor was pulled down by the contraction. The belt was guaranteed water proof, or as the manufacturers said, "Commercially water proof."

19 The main claim of these belts is low first cost, but they should not be used on permanent installations, particularly where out of doors, or where subject to atmospheric changes.

20 The rubber covered belt is more generally used than any other type, and the belt conveying industry has been built up mainly on the remarkable showing of the rubber belts made by Mr. Robins, based on the tests described previously. While belt conveyors had been used for many years for handling grain, and to some extent for other materials, the apparatus was crude and mostly home made, so that the real development may be said to start with the perfection of a durable rubber belt.

21 Briefly, rubber belts are made as follows: The duck is run through the calender which consists of a series of heated rolls. This machine coats the duck with rubber, known as "friction." This frictioned duck is then cut into the proper widths and the belt is laid up to the desired number of plies, the operator using a hand or power roller to cause the plies to stick together. The cover is then put on and the belt put in the vulcanizing press where it is subjected to heat and pressure. The belts are stretched before being vulcanzed.

22 It will be noted that the belt consists of three parts: First, the duck which gives tensile strength; second, "friction," which cements the plies of duck together; third, the rubber cover which protects the duck from moisture and abrasion.

23 Cotton duck used in the manufacture of belts is made in bolts about 375 to 400 ft. long. Belts longer than this should be joined with metal lacing. Internal splices should be avoided, and special lengths of duck, while sometimes used, generally cause delay and increased cost and are not to be recommended, especially in wide belts, on account of the increased weight of the roll of belting to be handled in shipment and erection.

24 The average manufacturer of rubber goods will, in making up belts, cut his duck so as to have the least waste, as the narrow strips are almost valueless. This results in the longitudinal seams in the belt being located at random. A careful study of hundreds of belts operating under a great variety of conditions has shown the great importance of the proper location of these seams. When properly placed, they cause no trouble, while many belts made by reputable rubber companies have gone to pieces in a few months because the manufacturer did not understand the conditions under which the belts must operate, and naturally built them only with regard to his factory economy as a guide to construction. The real life of the rubber belt is in the cover, provided of course, the belt is properly laid up and the friction is good.

25 A thin layer of rubber forming the cover of a belt under observation handling iron ore was found to represent one-half the life of the belt, although forming less than one-fifth the total thickness. The function of the cover is to protect the body of the belt from moisture and abrasion. It must therefore be soft, pure and durable, and still not be too high in cost. The compounds forming the covers were determined by the sand blast and ore tests previously described and since the time of these tests the compounds have been greatly improved by a careful study of belts in actual service.

26 Much harm has been done to this industry by the fact that the buyer has not, as a rule, a very extensive knowledge of rubber and he cannot, from the samples submitted by a rubber company, be sure that he is getting a belt suited to the work to be performed. The specialist in the manufacture of belt conveyors has his business at stake when he offers his product, and should the belts fail his whole business suffers. The ordinary salesman of rubber belts on the other hand does not, as a rule, have an opportunity to study the operating conditions of belt conveyors and should the belts fail, he blames the mechanism, while the purchaser condemns the system. It is therefore more satisfactory to purchase the complete conveyor from the specialist who knows the conditions and can be held responsible.

27 Rubber belts are absolutely water proof *only when the cover is intact*, as the friction coats only the surface of the duck and is not absorbed by the same. When used in such service that the belts are continually soaked in water, they are seriously damaged by the water reaching the duck through cuts or punctures in the covers. The duck absorbs the water, causing the rubber to lose its hold, thus forming a blister which is quickly extended by passing over the end pulleys.

This does not apply so much to belts working out of doors and subject to wetting from storms, as to those handling dredgings, wet tailings and similar materials.

28 It will be noted that both the cotton and rubber belts lack the property of being absolutely water proof. The only belt, which to the writer's knowledge possesses this quality, is the Dick's Balata Belt.

29 Balata is a vegetable gum found in Venezuela and the Dutch East Indies. In nature it lies between gutta percha and india rubber, but differs from them in its great tensile strength, freedom from oxidation, and the fact that it does not deteriorate with age. It is dissolved properly in but one solvent, the nature of which is a carefully guarded secret of the manufacturers.

30 The duck used in the Dick belt is woven by a special process on powerful looms, making it a very compact, closely woven, and non-stretching fabric. The Balata is applied to the fabric in a liquid form so that the gum penetrates and saturates every fiber of the fabric thoroughly waterproofing same. This belt is not only water proof, but it possesses about 20 per cent greater tensile strength than a rubber belt of the same number of plies, due to the more closely woven fabric and the greater strength of Balata as a friction. The fabric is never exposed to the great heat of vulcanization, which seriously impairs the strength and vitality of the fabric used in rubber belts. For lighter materials, the Balata Belts are used without cover, but when heavy abrasive materials are to be handled a rubber cover is provided to protect the fabric from wear.

31 There are two points which determine the number of plies of duck making up a conveyor belt. First, there must be sufficient tensile strength; second, the belt should have enough stiffness to support the load properly between idlers. With the speed and the power transmitted known, the stress in the belt per inch of width may be determined and this stress should not exceed 18 to 20 lb. per in. per ply on the rubber belts, although it may be increased 20 per cent on Dick's belts. Where the power required is small, the stiffness of the belt fixes the number of plies. From 12 in. to 14 in. they should not be under 3 ply; 16 in. to 20 in. not under 4 ply; 22 in. to 28 in. not under 5 ply; 30 in. to 36 in. not under 6 ply.

32 Belts are sometimes made endless in the factory, but they are difficult to install and nothing is gained, so this practice is not recommended.

33 Lapped splices have been vulcanized in the field with a portable press, but this requires an expert and is very difficult as all mois-

ture must be dried out of the duck, otherwise steam will form when heat is applied, forming a blister in the splice. Lapped cemented splices are sometimes used, copper tacks being driven through the belt to hold the edges down. All of these methods are necessary in some cases, but generally a metallic lacing like the Bristol or the Crescent lacing, Fig. 9, are the most satisfactory. These lacings are strong, are easily put in and do not seriously damage the ends of the belt,

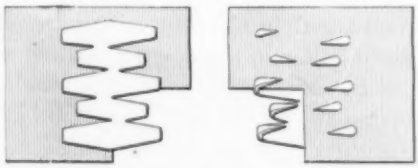


FIG. 9 METALLIC LACING

provided the holes are first punched with an awl. When the belt becomes worn at the edges of the lacing, it is a simple matter to cut the lacing out and put in a new row.

DRIVING MACHINERY

34 The belt conveyor has one great advantage over most other types of conveyors, in that it may be driven from any point in its length. When properly designed, the drive located at the tail or loading end will prove as satisfactory as when at the head. The drive may be located on the return or lower belt at any point between the head and tail ends with satisfactory results. The longest heavy duty belt conveyor ever built (1000 ft. from center to center, handling about 400 tons of material per hour) is driven from the loading end. This feature of being able to apply the power to the conveyor at any point in its length, is of great value in the design of plants, particularly with conveyors of large capacity.

35 Take, for example, the case of a long, inclined conveyor, running up an inclined structure, the drive may be located at the foot of the incline where proper foundations may be obtained and where the heavy parts may be conveniently and cheaply handled. Any other type of conveyor would require a drive located at the top of the incline, greatly increasing the cost and weight of the supporting structure, with corresponding increase in cost of installation. Where

one conveyor discharges to another, they may be driven by a single motor or engine at the point of intersection, one being head, the other tail driven. A conveyor carrying tailings from a mill to a waste pile may be driven from the shafting of the mill by tail drive, thus saving wiring to the head end and an isolated motor.

36 It is frequently desirable to drive one conveyor *through* another, using the conveyor belt to transmit the power. For example, in a system of four conveyors, A, B, C, and D, material was fed to A which discharged to B, B to C and C to D. A motor was located at the point where B discharged to C. Power was transmitted from the head of B through the belt, and A was connected by suitable gears and chain to the tail of B. Similarly conveyor C was driven at the tail end and D was geared to the head of C. It will be noted, therefore, that the four units were geared to a single motor located at a convenient point along the line and arranged so that they all started or stopped at the same time.

37 The drive located at any point in the length of the conveyor may be so built that the conveyor may be reversed, thus carrying material in either direction by simply reversing the motor or engine.

38 The driving machinery for the belt conveyor is extremely simple. Power is applied to one or more of the pulleys over which the conveyor belt passes. These pulleys should have heavy arms and rims with extra high crowns. They should be secured to their shafts by both keys and set screws.

39 Formerly the driving pulleys were increased in diameter as the duty increased, so as to obtain a greater arc of contact. In recent years multiple pulley drives have been used on the longer conveyors with most satisfactory results. In this type of drive, the belt passed over two or more pulleys geared together so they would turn at the same speed. This makes it possible to use smaller pulleys, thereby simplifying the speed reduction from the motor or engine. For example, a conveyor with a belt speed of 400 ft. per min. having a driving pulley 48 in. in diameter making 32 r.p.m. and driven by a motor at 800 r.p.m. will require a reduction of 25 to 1. If a multiple pulley drive made of two 24 in. pulleys is used, the reduction will be only 12½ to 1. With a single pulley drive, the belt must always be under the proper driving tension fixed by the take-ups. With the multiple pulley drive, however, the belt may be run as slack as desired provided there is some means of keeping the belt in contact with the second drive pulley, by allowing it to sag or using a weighted take-up. A belt under great tension is hard to train, therefore the conveyor with multiple pulley drive may be more easily adjusted and operated.

40 Pulleys of small diameter should be avoided on the heavy belts, otherwise the constant bending when under heavy stress will cause the friction to lose its hold and destroy the belts. In many cases it is advisable to cover the driving pulley with a rubber lagging to increase the tractive power. This is particularly the case when the conveyor operates in a dusty place.

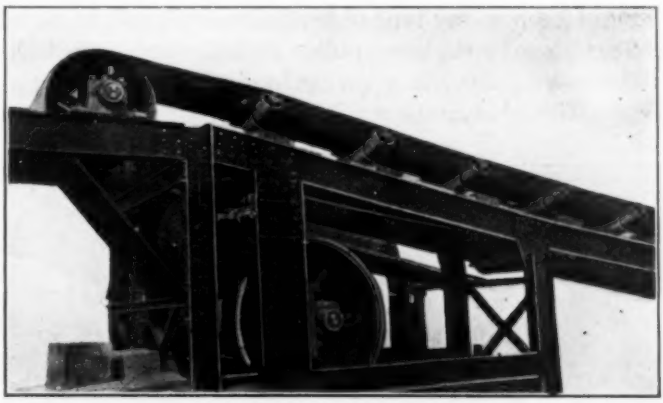


FIG. 10 HEAD DRIVE—DRIVING DONE BY LARGER PULLEY

41 The following table gives the minimum size of driving pulleys which should be used on the various widths of belt dependent on the number of plies:

TABLE I MINIMUM SIZE OF DRIVING PULLEYS

Width of Belt Inches	Diameter of Driving Pulley Inches	Width of Belt Inches	Diameter of Driving Pulley Inches
12	16 to 18	26	24 to 30
14	16 to 18	28	24 to 30
16	18 to 24	30	30 to 36
18	20 to 24	32	30 to 36
20	20 to 24	34	30 to 42
22	20 to 30	36	30 to 48
24	24 to 30		

42 Only two or three sizes of pulleys are required for each width of belt to make up drives for conveyors of the various lengths. A short conveyor may be driven by a single bare pulley; a longer con-

veyor may be driven by a pulley of the same diameter if it is covered with rubber. Still longer conveyors would use a two-pulley drive with bare pulleys. These in turn may be rubber covered, giving still greater tractive power. The faces of all pulleys should be at least 2 in. wider than the belt. At some point in the length of the conveyor, a pair of take-ups should be used to take up the stretch in the belt, and to adjust same should the splice not be exactly square.

43 Fig. 10 shows one type of head drive. It will be noted that the driving is done by the larger pulley, while the material is discharged over the smaller pulley, thus saving head room and giving a clean discharge. This photograph was taken before the chute was placed.

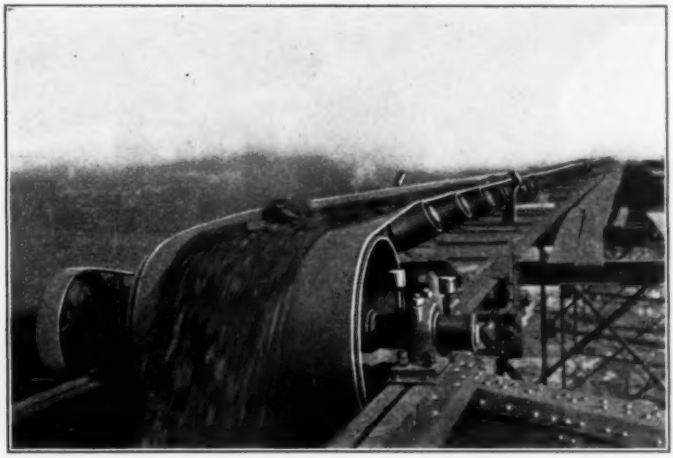


FIG. 11 DISCHARGE AT HEAD OF CONVEYOR

44 Fig. 11 is the discharge at head end of a conveyor. The drive is located at the foot of the incline on the ground, 300 ft. away. The pulley on the left drives the rotary brush. Capacity 600 tons per hour.

DISCHARGING DEVICES

45 Most conveyors receive material at one end or at various points in their length and discharge same over the head pulley. When necessary to discharge at points between the ends, either fixed or movable trippers are used. The fixed tripper consists of two pulleys, one located above and ahead of the other. The belt passes over the

upper pulley then over the lower in such manner that the material is discharged from the belt into a chute which will carry same to the side of the conveyor.

46 When fine sized material is being conveyed, these trippers may be made automatic, so that the stream of material will be deflected into the first bin until filled. The material will then fill up in the chutes, flow back on itself to the belt and be carried to the second tripper, and so on until all bins are filled. Should material be drawn from any bin, the stream will immediately be deflected until the bin is again filled and then pass on. The writer has used eight such trippers on a single conveyor.

47 The movable or traveling tripper is similar to the fixed tripper in form and operation. The two pulleys and chute are mounted

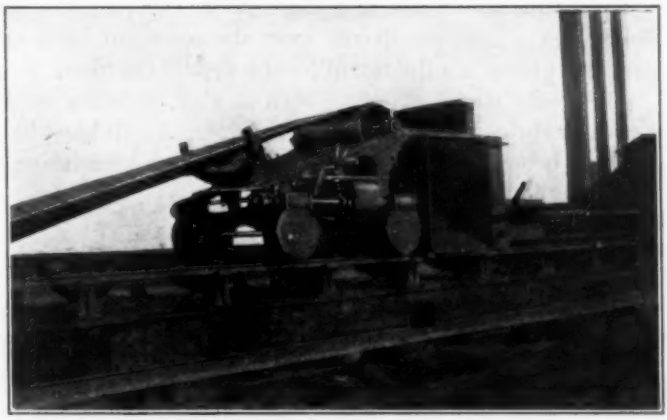


FIG. 12 AUTOMATIC SELF-REVERSING TRIPPER

on a frame supported on four flanged wheels. A pair of rails extending the length of the conveyor provides track for the machine and enables it to discharge material at any point in the length of its travel. The tripper is usually provided with some clamping device to secure it to the rails when discharging in a fixed position.

48 Trippers are moved in the following ways: The hand propelled type is moved by crank with pinion and gear to the truck wheels. Others use a wire rope with winch located at one end of the conveyor. The self propelled tripper is driven by power taken from the conveyor belt, through suitable gearing to the truck wheels. The automatic self reversing type is illustrated in Fig. 12.

49 A lever on one side properly connected with the driving mechanism controls the direction of travel of the machine. This lever engages adjustable stops located on the rails at the desired limits of discharge and the tripper will travel between these stops, automatically reversing at each end. A lever is provided which will throw this moving mechanism out of gear allowing the machine to discharge in a fixed position.

CLEANING BELTS

50 When the material handled is damp it is advisable to provide some mechanism to clean the belt after it passes over the discharge pulley; otherwise a small quantity will be carried back by the return belt. For this purpose, rotary brushes, made of various fibers, are used. These brushes revolve at a high speed, sweeping the material into the chutes. They are driven from the conveyor belts and are provided with means of adjustment for the wear of the fiber.

51 When very sticky material, such as clay, is being conveyed, a strong water spray is used to clean the belts. An air blast has been used to clean belts, but the large volume and high pressure required makes this method expensive.

CHUTES AND FEEDERS

52 One of the most important features of belt conveyor design is that of providing chutes which will properly load the material onto the belt. Mine run ore may be fed to a belt conveyor so that it will not injure the belt, but with improperly designed chutes the highest grade belt may be ruined in a few weeks when it should last for years.

53 It is impossible to lay down any rules for the design of chutes. It is a subject requiring a careful study of local conditions and a complete knowledge of the materials handled and of the manner in which they will move in chutes under various conditions.

54 The material should always be delivered to the belt in the direction of the belt travel and as nearly as possible at the same speed, so that it will go from chute to belt with no shock or jar. When feeding a conveyor from bulk, for example, from storage bin, some type of automatic feeder should be used to insure an even and continuous feed to the belt. This is particularly important when handling unsized material. Should a simple gate be used, it must be set for the large lumps, the result being a rush of fine material after the lump has

passed. If a feeder is so driven that it will start and stop with the conveyor it feeds, it will generally save the expense of an attendant at the loading end and prove more satisfactory.

55 The writer favors the shaking feeder consisting of an inclined pan set under the bin opening at such an angle that it stops the flow when stationary. When given a reciprocating motion by crank and connecting rod the material is moved along the pan to the belt. By varying the length of stroke and inclination of the pan the amount of material delivered may be absolutely regulated.

CAPACITY

56 Belt conveyors may be built to handle practically any quantity of material which may be fed to them. The following table gives the capacity, maximum size of lumps, and advisable speed for the differ-

TABLE 2 BELT CAPACITY AND SPEED

Width of Belt	Maximum size of pieces	Capacity in cubic feet per hour at a belt speed of 100 ft. per min.	Capacity in tons per hour, at a belt speed of 100 ft. per min., material weighing 100 lb. per cu. ft.	Maximum advisable speed in feet per minute	Capacity in cubic feet at the maximum advisable belt speed	Capacity in tons per hour at the maximum advisable belt speed material weighing 100 lb. per cu. ft.
12	2	460	23	300	1380	69
14	2½	630	31	300	1890	94
16	3	820	41	300	2460	123
18	4	1040	52	350	3640	182
20	5	1280	64	350	4480	224
22	6	1550	78	400	6200	310
24	8	1850	93	400	7400	370
26	9	2180	110	450	9810	490
28	12	2500	125	450	11250	563
30	14	2900	145	450	13050	653
32	15	3300	165	500	16500	825
34	16	3700	185	500	18500	925
36	18	4200	210	500	21000	1050
38	19	4600	230	550	25300	1265
40	20	5100	255	550	28050	1402
42	20	5600	280	550	30800	1540
44	22	6200	310	600	37200	1860
46	22	6800	340	600	40800	2040
48	24	7400	370	600	44400	2220

ent widths of belts. This table is based on an even and continuous flow of material to the conveyor and in choosing width and speed, a full knowledge of the local operating conditions, and character of the material, is necessary so that the table may be used with judgment.

SPEED AND SIZE OF BELTS

57 When the quantity to be conveyed is small, and the pieces large, the size of the material fixes the width of the belt and the speed should be as low as possible to safely carry the desired load.

58 When the quantity is great, the capacity fixes the width and in this case also the speed should be as slow as possible. A slow speed belt may be loaded more deeply than one at high speed and when a narrow belt is run much above the advisable speed, the load thins out and the capacity does not increase as the speed.

59 The maximum length of the different widths of conveyors is determined by the fiber stress in the belt and is therefore closely related to the load and speed. Naturally level conveyors may be built longer than those lifting material. Conveyors 1000 ft. from center to center handling 500 tons per hour have been most satisfactorily operated.

60 Another important factor in the design of conveyors at high speed, handling large quantities, is the flow of material in the chutes. A 36 in. conveyor handling 750 tons of coal per hour with a belt speed of 750 ft. per minute under a 10 000 ton pocket could not be loaded from a single chute, because it was not possible for the coal to attain a speed of 750 ft. per minute in the chute. It was necessary, therefore, in order to obtain a full load to open seven gates, each placing a layer of coal on the belt until the desired load was obtained. During a test this belt carried about 800 tons per hour.

POWER REQUIRED

61 The power required to drive a belt conveyor depends on a great variety of conditions such as the spacing of idlers, type of drive, thickness of belt, etc.

62 In figuring the power required, it is important to remember that the belt should be run no faster than is required to carry the desired load. If for any reason it is necessary to increase the speed, the load should be increased in proportion and the power figured accordingly. In other words, the power should always be figured for the full capacity at the chosen speed, as follows.

C = Power constant from table
T = Load in tons per hour
L = Length of conveyor between centers in feet
H = Vertical height in feet that material is lifted
S = Belt speed in feet per minute
B = Width of belt in inches

For level conveyors,

$$\text{H. p.} = \frac{C \times T \times L}{1000}$$

For incline conveyors

$$\text{H. p.} = \frac{C \times T \times L}{1000} + \frac{T \times H}{1000}$$

Add for each movable or fixed tripper horse power in column 3 of table.

Add 20 per cent to horse power for each conveyor under 50 ft. in length.

Add 10 per cent to horse power for each conveyor beteeen 50 ft. and 100 ft. in length.

The above figures do not include gear friction, should the conveyor be driven by gears.

TABLE 3 POWER REQUIRED FOR GIVEN LOAD

	1	2	3	4	5
Width of Belt	C for material weighing from 25 lb. to 75 lb. per cu. ft.	C for material weighing from 75 lb. to 125 lb. per cu. ft.	H. P. required for each movable or fixed tripper	Minimum plies of belt	Maximum plies of belt
12	.234	.147	½	3	4
14	.226	.143	½	3	4
16	.220	.140	¾	4	5
18	.209	.138	1	4	5
20	.205	.136	1¼	4	6
22	.199	.133	1¼	5	6
24	.195	.131	1½	5	7
26	.187	.127	2	5	7
28	.175	.121	2¼	5	8
30	.167	.117	2½	6	8
32	.163	.115	2¾	6	9
34	.161	.114	3	6	10
36	.157	.112	3¼	6	10

63 With the load known, choose from the capacity table the proper width of belt and proper speed. The above formulae give the horse power required for the conveyor when handling the given load at the proper speed. With the horse power and the speed known, the stress in the belt should be figured by the following formula in order to find the proper number of plies. Stress in belt in pounds per inch of width $= \frac{\text{h. p.} \times 33\,000}{S \times B}$ With this value known, the number of plies may be determined, using 20 lb. per inch per ply as the maximum. The columns four and five of Table 3 give the maximum and minimum advisable plies of the different widths of belt. Belts between these limits will trough properly and will be stiff enough to support the load. The maximum number of plies determines the maximum length for each width of conveyor.

ARRANGEMENT OF CONVEYORS

64 Fig. 13, A, shows in outline the simplest form of level conveyor receiving material at one or more points and discharging over the end pulley.

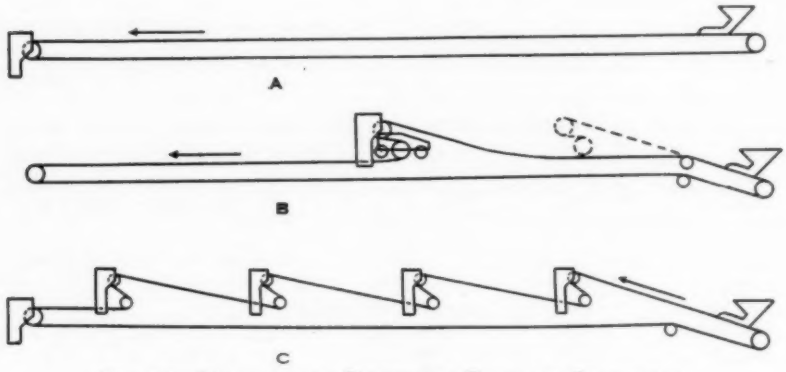


FIG. 13 DIAGRAMS OF DIFFERENT TYPES OF CONVEYORS

65 In Fig. 13, B, the material is received at one end and discharged at any point in the length by a movable tripper. The tail end is usually depressed as shown so that the belt will not be raised against the loading chute by the tripper when discharging near the tail end as shown in dotted lines. Fig. 13, C, is a level conveyor with a series of fixed dumps.

66 Fig. 14, A, shows the simple inclined conveyor. Practically any material may be carried up 20 deg. to the horizontal when run at proper speed and with correctly designed chutes. With sized material, such as sand, crushed ore, stone or coal, the angle may be increased to 22 deg. and under some conditions, even more. When elevating material containing large lumps, the lumps have a tendency to roll back on the layer of fines so that the angle should not be over 20 deg. When handling round material, such as cement clinkers from rotary kilns, the angle should be from 12 deg. to 15 deg. maximum. Inclined conveyors should not be run at high speeds, as the material must be given the same speed as the belt and the higher the speed the more the slip at the loading point and the greater the wear on the belt.

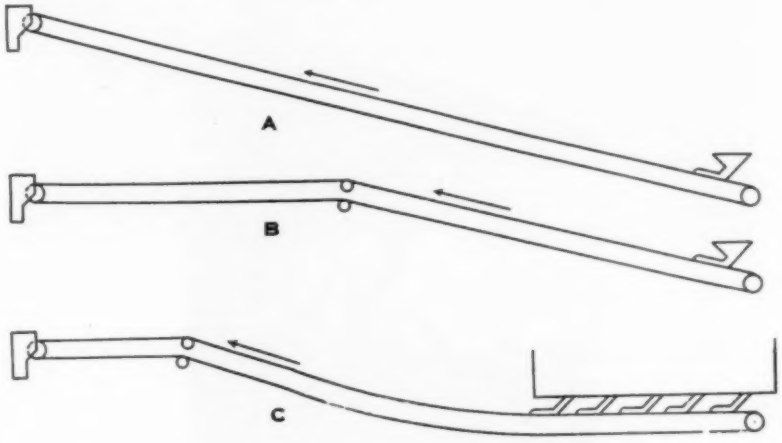


FIG. 14 DIAGRAMS OF INCLINED CONVEYORS

67 Fig. 14, B, is the combination of inclined and level conveyor which is largely used. Where the belt passes from the incline to the level it should not pass over a troughing idler but over a high crowned pulley. This flattens the belt out at the bend and the material will leave the belt on a trajectory and land on the level portion with no spill, because belt and material are moving at the same speed.

68 It is frequently advisable to run conveyors on a vertical curve. Fig. 14, C, illustrates the combination of curved and level conveyor. The radius of the curve depends on the size of the belt, location of the drive and the local conditions. It is possible to so design these

conveyors that the belt will touch the troughing idlers, whether loaded or light. Should the belt lift off the idlers on the curve, it reduces the driving tension on the belt, which should be avoided. Fig. 15 is a photograph of the lower end of a conveyor on a curve.

69 Fig. 16 is a photograph showing the discharge from a level conveyor to the inclined portion of another, and illustrates the method of making the bend and the action of the material at this point.

70 Fig. 17, A, shows the combination of level conveyor, fixed dump, inclined conveyor and a number of fixed trippers. Frequently

FIG. 15 LOWER END OF CONVEYOR ON CURVE

it is not possible to obtain the room required for the curve belts, so the fixed dump is used. The material is discharged from the upper pulley of the dump into a chute feeding the inclined portion of the same belt. The fixed and movable trippers may be used with any of the above combinations where a portion of the conveyor is level or not inclined over 7 deg.

71 Fig. 17, B, is a diagram of still another combination, in which the conveyor starts level, carries material down hill with an incline and curve and then runs level again. Fig. 18 is a photograph of such a conveyor receiving material from the hoisting towers in the distance

FIG. 16 DISCHARGE FROM LEVEL TO INCLINED CONVEYOR

and running down hill in a concrete passageway under railroad tracks and highway.

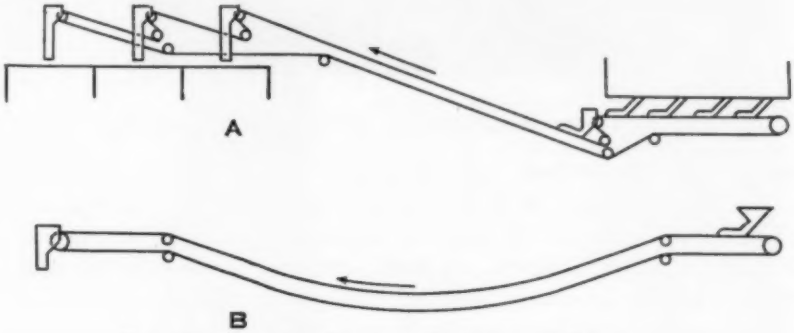


FIG. 17 DIAGRAMS SHOWING COMBINATION TYPES

72 Fig. 19 is a photograph of the conveyor dredge used to deepen Fox River, Wisconsin. The endless chain of buckets dig the mud, clay,

rock, etc., from the river bed, discharging to a 32 in. conveyor carried by the dredge. Three other conveyors mounted on scows carry the material to either shore, as may be desired, with but the one handling. The conveyors first used on this dredge were not satisfactory owing to incorrect design and they were rebuilt last year, one conveyor being equipped with rubber belt and three with Dick's Balata Belt. The latter proved more satisfactory, owing to its water proof qualities.

73 Fig. 20 illustrates a large coal storage plant. The coal is hoisted from vessels by the towers on the dock and fed to a 36 in. con-

FIG. 18 CONVEYOR RUNNING IN CONCRETE SUB-PASSAGEWAY

veyor about 600 ft. long back of towers. This conveyor discharges to one running along the end of the pile, about 300 ft. in length, discharging to the tail of the inclined conveyor about 500 ft. long, to the left of the photograph. A 50-ft. conveyor carries the material from the top of the incline to the center of the pivot point of the bridge. A chute at this point feeds the 500 ft. tripper line carried by the bridge. The bridge swings through 180 deg. and the travel of the bridge and the movement of the tripper the length of the bridge conveyor makes it possible to receive coal at any point along the dock and store same at

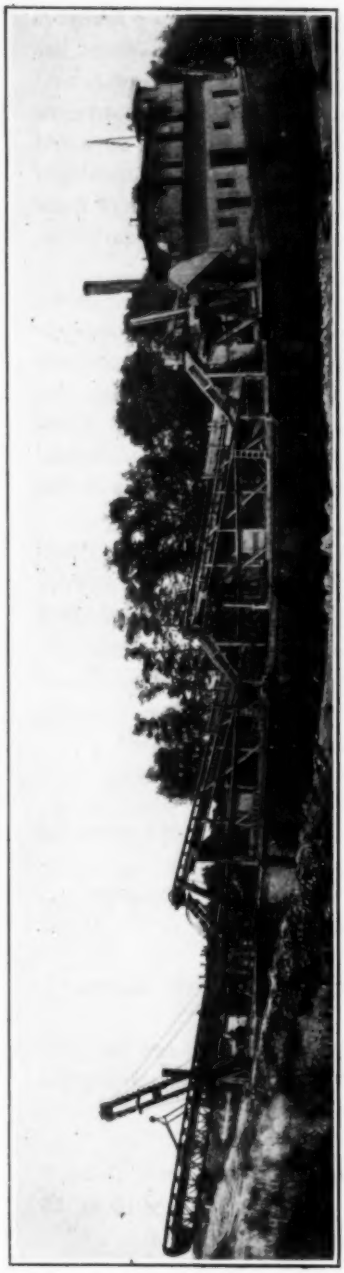


FIG. 19 CONVEYOR DREDGE

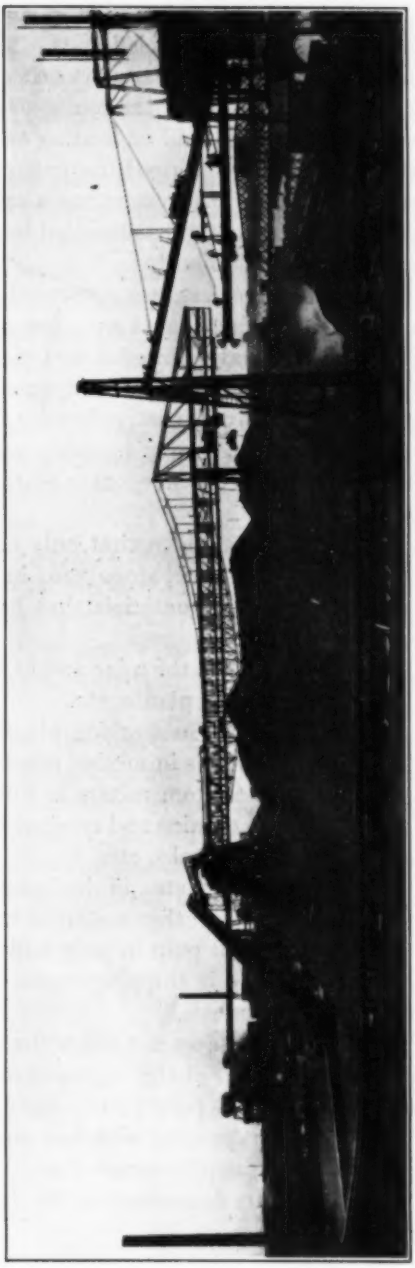


FIG. 20 COAL STORAGE PLANT

any desired location in the storage space. The first two conveyors are driven from their head ends. The inclined belt is driven at the foot of the incline. The short belt at the top is driven by gears and chain from the head of the conveyor feeding it. The bridge conveyor is driven from the tail or loading end. All the motors are so wired that they may be stopped from any point along the line by means of push buttons. This system has a capacity of about 700 tons of mine run coal per hour and has handled in the past three seasons nearly one and a quarter million tons.

74 This paper has been presented mainly to acquaint the engineers who are designing plants with the possibilities of the belt conveyor for handling heavy abrasive materials, and to give them some data which will be of service in the preparation of preliminary designs. No one type of conveyor is perfect for handling every material. Each has its field, but it may be fairly said that it has become universal practice to use belt conveyors in places where ten years ago only chains were considered.

75 The ancient idea that only conveyors made of iron or steel could handle coal, ore, stone, etc., has been exploded and the following is a list of the materials that belt conveyors are most satisfactorily handling:

Coal in all sizes at the mine and in industrial plants.

Stone in crushing plants, etc.

Sand and gravel in washing plants, etc.

Concrete materials in mixing plants.

Mixed concrete from mixers to forms.

Ore, both run of mine and crushed in concentrating plants, crushing plants, reduction works, etc.

Earth, rock, clay, etc., in dredging and excavating operations.

Cement rock and other materials in cement mills.

Wood chips and pulp in pulp mills.

Small packages in shipping rooms of stores, and express depots.

Salt and chemicals.

76 The writer does not claim that the belt conveyors are the panacea for all the ills of the conveyor user, but when properly designed and installed, they fully justify the following claims:

a Large capacity with low power requirements.

b Small maintenance charges. Belts will last from 3 to 8 years dependent on the duty. Idlers and drives 10 to 15 years.

c Freedom from shut down, as there are no links to break and a belt will give months of warning before giving out.

d Light weight, resulting in lighter structures and saving in freight, particularly in ocean shipment and at isolated mining plants.

e Complete separation of the material carried from the moving parts—the material coming in contact only with the belt.

f Perfect alignment is not absolutely necessary as is the case with most other conveyors. The long incline conveyor to the left of Fig. 20 was built on a swamp. The two bents near the head tower shifted 10 in. and the conveyor was operated in this condition for nearly one month with no trouble or damage to the apparatus.

g Owing to light weight and the fact that perfect alignment is not necessary, they may be made up in portable sections, which are in great demand.

h Large overload capacities.

77 The above claims are based not on a few months' research, but on years of service as a mechanical engineer with one of the large anthracite coal mining companies and over eight years devoted entirely to the design, manufacture and installation of belt conveyors, the early years being pioneer work when the industry was in its infancy.

78 In choosing illustrations for this paper, preference has been given to the line drawings and photographs illustrating parts of conveyors rather than those which show complete installations, as the object has been, not to describe existing plants, but to bring out the principles of the mechanism. Acknowledgment is due the companies who have consented to the use of photographs taken at their plants.

CONTINUOUS CONVEYING OF MATERIALS

By Staunton B. Peck, Chicago, Ill.

Member of the Society

CHAIN CONVEYORS

The manufacture of conveying machinery, and its adaptation to the various industries, dates from the year 1880, when a company was incorporated for manufacturing and developing such machinery. This company was organized by the manufacturers of the Ewart detachable link belt in response to the demand for these links with attachments to which pushers or buckets could be fastened, and to requests for advice about their utilization for all sorts of conveying purposes.

2 Although the development of this class of machinery began nearly 30 years ago, there is scarcely any literature on the subject outside of trade catalogues and comparatively few industries follow such uniform methods, or handle materials in such quantities, as to have developed standard designs for their conveying equipment. Figures upon economies effected have not been kept to the extent they should have been. Managers of industrial plants are generally satisfied with the apparent fact that there is a material saving and do not take the trouble to ascertain just how much this is, or whether it might not be greatly increased by the use of conveyors of improved construction.

3 This lack of information has given first cost an altogether unwarrantable importance in determining the character of installations of this kind. The initial cost should always be given its due consideration, but should not be used as a cloak for ignorance.

To be presented at the Detroit Meeting (June 1908) of The American Society of Mechanical Engineers.

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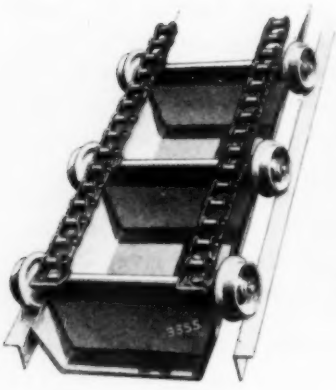
The Society as a body is not responsible for the statements of facts or opinions advanced in papers or discussions. C55.

Unfortunately a very large proportion of conveying plants are, from the nature of their service, very dirty and so located that investigation is conducted with more or less discomfort, but this should not

FIG. 1 CONVEYOR WITH SLIDING WEARING SHOES



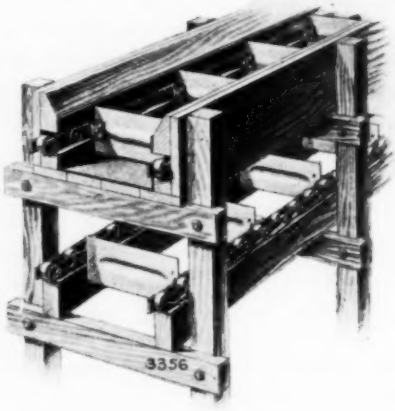


FIG. 2 FIG. 3

FIG. 2 ROLLER FLIGHT CONVEYOR
FIG. 3 REVERSIBLE FLIGHT CONVEYOR

deter engineers from such investigation. The infinite variety of physical characteristics presented by materials handled indicates in itself the likelihood of wide variations in the designs of conveying machin-

ery to meet these conditions, and the necessity for careful examination of both design and details of construction by the engineer who is called upon to decide between different plans that may be submitted to him.

4 The development of the conveying art has been greatly assisted by the industrial consolidations of the last seven or eight years. These have increased the raw and manufactured products of existing plants and have led to the building of new plants of such size that the economical handling of materials in process has wisely been considered from the outset and has had its determining influence on the plan as a whole. It is with such initial consideration, and in such plants,

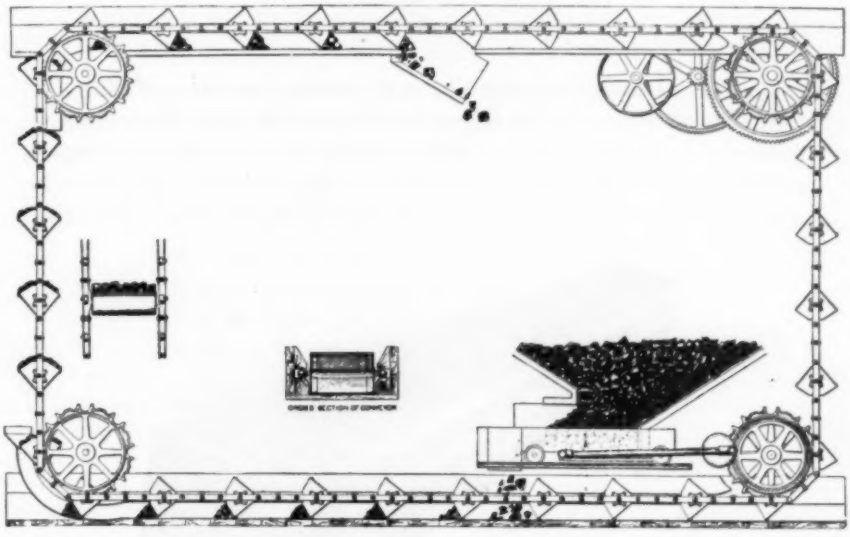


FIG. 4 BUCKET CONVEYOR WITH RIGID BUCKETS

that the conveying art has reached its highest development and effected its greatest saving. In the discussion which follows some of the types of conveyors are considered which have proved most efficient and are in most general use.

5 Conveyors for the continuous handling of materials may be divided into two general classes:

(*a*) Those which push or pull their load, the weight of the load not being borne by the moving parts of the conveyor.

(*b*) Those which actually carry the material handled.

6 Conveyors of the first class push or pull the material handled along in a trough. The friction of the conveyor itself and the material conveyed on the trough consume power and cause wear. Hence the field of usefulness of conveyors of this type is confined to relatively small conveyors with light service; or in the larger installations, to the handling of materials with a low coefficient of friction and which are not abrasive in their action, such as coal, grain, etc.

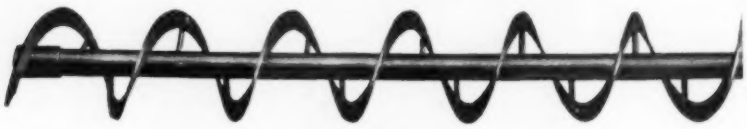


FIG. 5 SPIRAL CONVEYOR

7 One of the oldest forms, which, from its simplicity and comparatively low first cost is still one of the most extensively used, consists merely of an endless chain to which are attached at intervals scrapers or flights. The improved forms of this conveyor, now most generally used, have sliding shoes or rollers attached to the flights or the chains,

FIG. 6 SPIRAL CONVEYOR AND TROUGH

supported on runways. The flights are allowed to come very close to the trough bottom, but not actually in contact with it, thus reducing the friction upon the trough to that of the material conveyed only. Fig. 1, 2, and 3 illustrate conveyors of this type, the rollers in Fig. 3 being an integral part of the chains.

TABLE 1 CONVEYING CAPACITIES OF FLIGHT CONVEYORS

in tons (2000 lb.) of coal per hour at 100 ft. per min.

SIZE OF FLIGHT	HORIZONTAL				INCLINED		
	Spaced			lb. per flight	10 deg. 24 in.	20 deg. 24 in.	30 deg. 24 in.
	16 in.	18 in.	24 in.				
4 by 10	33¾	30	22½	15	18	14¼	10½
4 by 12	42¾	38	28½	19	24	18	13½
5 by 12	51¾	46	34½	23	28½	22½	16½
5 by 15	69¾	62	46½	31	40½	31½	22½
6 by 18		80	60	40	49½	40½	31½
8 by 18		120	90	60	72	57	48
8 by 20			105	70	84	66½	56
8 by 24			135	90	120	96	72
10 by 24			172½	115	150	120	90

8 The horse power required handling anthracite coal, may be determined from the following formula; this taking no account of gearing or other driving connections.

$$H.p. = \frac{ATL - BWS}{1000}$$

T = net tons per hour.

L = length center to center in feet.

W = weight, chain and flights (both runs) in lb.

S = speed per minute in feet.

A and B are constants depending on inclination from horizontal, taken from Table 2.

TABLE 2

	Hor.	5 deg.	10 deg.	15 deg.	20 deg.	25 deg.	30 deg.	35 deg.	40 deg.	45 deg.
A	0.343	0.42	0.50	0.585	0.66	0.73	0.79	0.85	0.90	0.945
B	0.01	0.01	0.01	0.01	0.009	0.009	0.009	0.008	0.008	0.007

9 The common working speeds are from 100 ft. to 200 ft. per min. and the capacities are as shown by the following table, these conveyors in some cases handling upwards of five hundred tons per hour. Fig. 4 shows a modification of a conveyor of the general construction of Fig. 3, in which the flights are given the form of buckets. With this type the material will fall back into the buckets when the conveyor makes an upward turn and thus be elevated. On the turning of the conveyor again into a horizontal path, Fig. 4, the material partially flows out into the horizontal trough, whence it may be conveyed to the desired point of discharge. As this device combines in one machine the ability to handle material horizontally and vertically

it has a wide field of usefulness, limited by the disadvantages already referred to as incident to all conveyors drawing material along in a trough.

TABLE 3 CAPACITIES OF GRAVITY DISCHARGE ELEVATOR CONVEYORS

in tons of coal per hour at 100 ft. per min.

BUCKET	SPACING			
Length and width in inches	18 in.	24 in.	36 in.	48 in.
12 by 12	31.0	23.5	15.5	11.7
16 by 12	41.3	31.3	20.5	15.6
16 by 15	61.4	46.5	30.7	23.3
20 by 15	78.0	59.0	39.0	29.5
24 by 15	91.0	69.0	45.5	34.5
20 by 20	138.0		69.0	
24 by 20	165.0		82.5	
30 by 20	206.0		103.0	
36 by 20	248.0		124.0	
30 by 24		220.0	145.0	110.0
36 by 24		262.0	173.0	131.0
48 by 24		350.0	232.0	175.0

TABLE 4 HORSE POWER OF ELEVATOR CONVEYORS

SIZE OF BUCKET	12 by 12 in.			24 by 15 in.			36 by 20 in.		48 by 24 in.	
Spacing	18 in.	24 in.	36 in.	18 in.	24 in.	36 in.	18 in.	24 in	36 in.	48in.
H.p. for each 10 ft. vert. lift	0.46	0.35	0.23	1.35	1.0	0.67	3.8	1.9	3.5	2.7
H.p. for each 100 ft. hor. empty	1.2	1.1	0.9	1.7	1.5	1.3	2.4	1.6		
Do. handling anthracite	2.5	2.1	1.5	5.3	4.3	3.1	12.4	6.6		
Do handling bituminous	3.2	2.6	1.9	7.4	5.8	4.2	18	9.4		

Add 5 per cent for each turn.

SPIRAL CONVEYOR

10 The screw or spiral conveyor has a great advantage, aside from relatively low first cost, in its compactness and the small space it

occupies, adapting it to conditions where the conveyors have to be placed in a trench beneath the floor or where the maintenance of head room is an object. The conveyor consists of a steel ribbon wound spirally about a shaft revolving in a trough which it fits approximately, the spiral being interrupted for a space of two or three inches at intervals of eight or ten feet to permit the support of the shaft by hangers. In the smaller diameters—up to 12 in. or 16 in.—the spiral fits close to the shaft. In the larger sizes, running up to as much as 3 ft. or more in diameter, the spiral is a comparatively narrow ribbon attached to the shaft by occasional studs. (Fig. 5.) The depth of material that it is practicable to convey is approximately one-third of the diameter of the screw.

11 Spiral conveyors, like all scraper conveyors, are costly of maintenance when handling gritty materials, and in this case heavy cast iron sectional and renewable flights are used running in a cast iron trough with hangers having white iron bushings. It is considered good practice under these conditions to make the box in which the conveyor runs of a size considerably larger than the conveyor, letting the material form its own trough. On account of the torsional strain on the shaft, screw conveyors are not very generally used for lengths exceeding about 100 ft., though where the service is exceptionally easy like the handling of grain or cotton seed, this length may be greatly exceeded. The following table gives a fair idea of the conveying capacities:

TABLE 5 CAPACITIES OF SPIRAL CONVEYORS IN CUBIC FEET OF MATERIAL CONVEYED PER HOUR, AT 100 R.P.M.

Diam.	6 in.	8 in.	10 in.	12 in.	14 in.	16 in.	18 in.
Cap.	260	660	1000	1660	2500	3660	5000

$$\text{H. p.} = \frac{\text{Capacity in lb. per min. times length in ft. by C}}{33\,000}$$

C is a constant and equals 0.67 for coal, 0.33 for grain, 1.00 for ashes

12 Still another conveyor which operates without the aid of a chain, and like the screw conveyor has the advantage of occupying but little space, is shown by Fig. 7 and 8. The flights are here attached by hinged connection to a bar or frame to which is given a reciprocating motion. On the forward stroke the flights push the

material ahead, and on the backward fold up over it by means of the hinge. The moving frame is carried by rollers and the stroke or amount of forward travel is usually from 2 ft. to 4 ft. This conveyor has been used principally in the handling of sand and materials that would cause too much wear of a screw conveyor.

13 The foregoing conveyors handle for the most part material in bulk. Conveyors of this class, where the flight takes the form of a projecting spur, pusher or hook, are widely used for log hauls and car hauls, and also to some extent for packages and boxes, either horizontally or at an inclination. Such conveyors put in beneath the floor and with the pushers projecting through a narrow slot in the floor have been very serviceable in the handling of trucks in warehouses and manufacturing establishments.

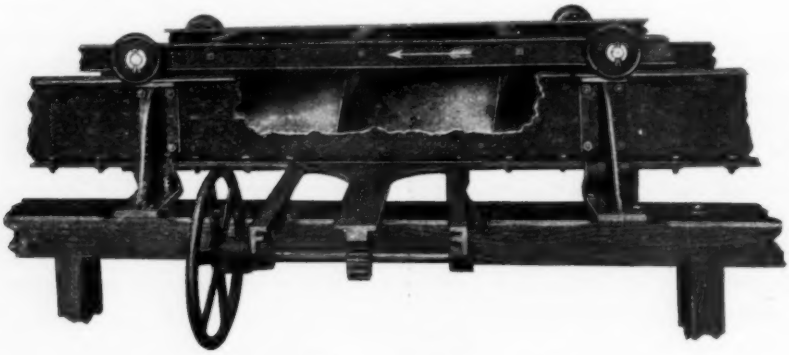


FIG. 7 RECIPROCATING CONVEYOR

BELT CONVEYORS

14 The general class of conveyors designated in the beginning as Class (*b*) which carry their load, have the more universal adaptation to varying requirements. Of these the conveying belt is one of the oldest and still most useful. To a limited extent, and for very light service, the belt may be supported by a trough; but almost universally is carried by rollers spaced on the carrying run from 2 ft. 6 in. to 5 ft. apart, and at intervals usually twice as great or more on the idle run. The earliest conveying belts were perfectly flat, being supported by plain cylindrical rollers such as are still used for the returning run. In order to increase the conveying capacity without the material spilling off the edges of the belt, the rollers were somewhat dished, or made concave in form, causing the belt to assume the form

of a shallow trough. In theory this is open to the criticism that but one diameter of the concave roller can travel at the speed of the belt, and some slipping must, therefore, take place at every other diameter of the periphery. Careful observations have shown, however, that the belts invariably fail in other ways before any injury from this slipping becomes apparent.

15 Before this fact was demonstrated, however, a supporting device, consisting of three independent rollers, the middle one horizontal and the side rollers inclined some 35 deg. or 40 deg. came into very general use, this arrangement giving the belt the form of a deep trough, and adding greatly to its carrying capacity.

16 Further modification of this was the substitution of two inclined center idlers for the one horizontal idler. This, while giving a relatively deep trough, overcame the sharp bends in the belt incident

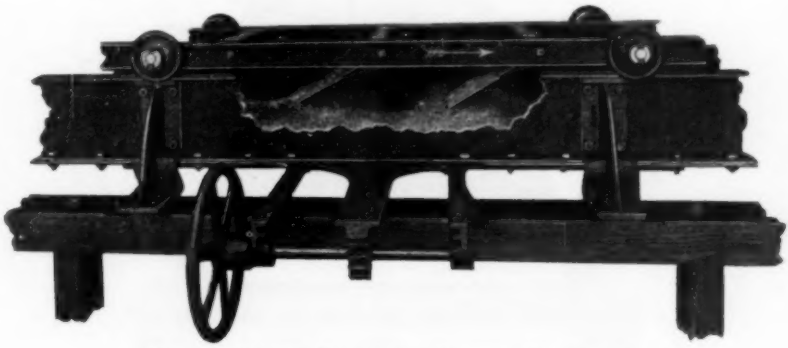


FIG. 8 RETURN MOVEMENT, FLIGHTS DEFLECTED

to the three roll support, and permitted the belt to assume a uniform curve. For belts of large capacity the four roll idler may, therefore, be considered the best modern practice. For smaller belts and moderate capacities, there is nothing better than the old concave roller referred to, which troughs the belt but slightly, and, therefore, insures the greatest durability.

17 The conveying belts themselves are of canvas duck, woven solid; or of a number of plies varying from three to eight, stitched or cemented together with a composition of rubber, and known as rubber belts. Canvas belts are plain duck, or treated with some preservative and painted with similar compound. For many kinds of service they meet every requirement. For severer duty, where the canvas fabric, which is the strength of the belt, must be protected as perfectly

as possible from dust, moisture,and cutting or wearing action, the rubber belts are preferable, and are usually made with a cushion of from $\frac{1}{16}$ in. to $\frac{1}{4}$ in. more or less pure rubber on the carrying side, which protects the fabric until this cushion is worn away. Special types of belts have been extensively used, some having fewer plies of canvas and a heavier cushion of rubber in the center where the belt is designed to receive and carry its heaviest load, and others having the fabric made thinner at the points where it is intended the belt should be bent to form a trough. Experience seems to show that the greatest durability is attained by avoiding a localized bending.

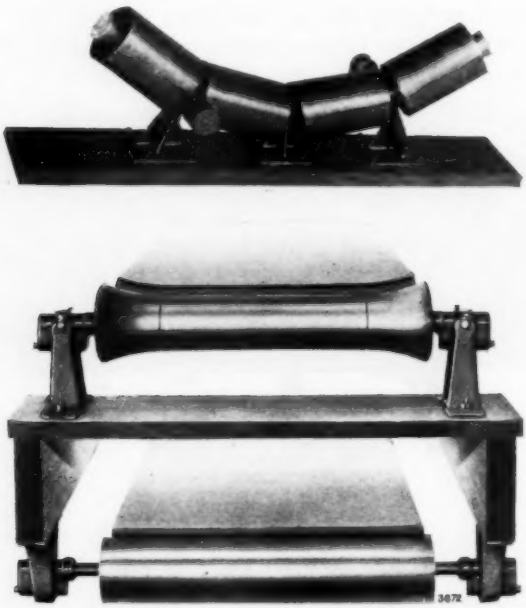


FIG. 9 RECENT TYPES OF ROLLER SUPPORT

18 The belt conveyor has a wide field of usefulness and is deservedly popular both with manufacturer and user. It is simple, smooth and noiseless in operation, may be run at relatively high speeds, from 300 ft. to 800 ft. per minute—with consequent large conveying capacity. On account of the expense of the belt, and the large number of supporting rollers which revolve at high speed, the initial cost and the power consumed in operation are much greater than would be sup-

TABLE 6 POWER REQUIRED FOR BELT CONVEYORS
at 100 feet per minute

Inclination of belt	HORSE POWER WITH DEEP TROUGHING ROLLS										HORSE POWER WITH SHALLOW TROUGHING ROLLS									
	Wt. of material 50 lb. per cu. ft.																			
	12	14	16	18	20	24	30	36	40	42	12	14	16	18	20	24	30	36	40	42
0 deg.	25	0.31	0.40	0.47	0.54	0.75	1.18	1.49	1.73	1.83	0.22	0.26	0.30	0.34	0.39	0.58	0.77	1.00	1.18	1.35
5	0.32	0.41	0.54	0.66	0.78	1.12	1.76	2.34	2.80	3.01	0.28	0.34	0.41	0.48	0.57	0.84	1.19	1.61	1.97	2.33
10	0.39	0.51	0.68	0.85	1.02	1.48	2.34	3.19	3.87	4.19	0.34	0.42	0.52	0.62	0.75	1.10	1.61	2.21	2.76	3.31
15	0.46	0.61	0.83	1.04	1.26	1.84	2.92	4.04	4.94	5.37	0.40	0.50	0.63	0.76	0.93	1.36	2.03	2.81	3.55	4.29
20	0.53	0.71	0.97	1.23	1.50	2.21	3.50	8.49	6.01	6.55	0.46	0.58	0.74	0.90	1.11	1.62	2.45	3.41	4.34	5.27
	Wt. of material 100 lbs. per cu. ft.																			
0 deg.	0.31	0.37	0.50	0.61	0.71	1.01	1.60	2.09	2.49	2.66	0.26	0.32	0.38	0.45	0.52	0.77	1.07	1.41	1.74	2.04
5	0.45	0.60	0.78	0.99	1.19	1.75	2.76	3.79	4.63	5.02	0.38	0.48	0.60	0.73	0.88	1.29	1.91	2.61	3.32	4.00
10	0.59	0.83	1.06	1.37	1.67	2.49	3.92	5.49	6.77	7.38	0.50	0.64	0.82	1.01	1.24	1.81	2.75	3.81	4.90	5.96
15	0.73	1.06	1.34	1.75	2.15	3.23	5.08	7.19	8.91	9.74	0.62	0.80	1.04	1.29	1.60	2.33	3.59	5.01	6.48	7.92
20	0.87	1.29	1.62	2.13	2.63	3.97	6.24	8.89	11.05	12.10	0.74	0.96	1.26	1.57	1.96	2.85	4.43	6.21	8.06	9.88

Add to the horse power for drive and head shaft 10 per cent if no discharger is used; 33 per cent with discharger; and 10 per cent for each 180 deg. idler.

TABLE 7 CONVEYING CAPACITIES FOR BELT CONVEYORS

at 100 feet per minute

	Capacities with deep troughing rolls										Capacities with shallow troughing rolls.									
Width of belt, inches	12	14	16	18	20	24	30	36	40	42	12	14	16	18	20	24	30	36	40	42
Capacity in cu. ft. per hr	320	450	670	900	1140	1700	2700	4000	5000	5500	280	390	520	670	840	1240	1950	2800	3700	4600
Capacities in bushels per hr	256	360	536	720	912	1360	2160	3200	4000	4400	224	316	416	536	672	992	1560	2240	2960	3680
Capacity in tons per hour: 46 lb. per cu. ft	6.4	9.0	13.4	18.0	22.8	34.0	54.0	80	100	110	5.6	7.8	10.4	13.4	16.8	24.8	39.0	56.0	74.0	92
50 " " " "	8.0	11.2	16.8	22.5	28.5	42.5	67.5	100	125	138	7.0	9.8	13.0	16.8	21.0	31.0	48.8	70.0	92.5	115
60 " " " "	9.6	13.5	20.1	27.0	34.2	51.0	81.0	120	150	165	8.4	11.7	15.6	20.2	25.2	37.2	58.5	84.0	111.	138
80 " " " "	12.8	18.0	26.8	36.0	45.6	68.0	108.0	160	200	220	11.2	15.6	20.8	26.8	33.6	49.6	78.0	112.0	148	184
100 " " " "	16.0	22.4	33.6	45.0	57.0	85.0	135.0	200	250	275	14.0	19.5	26.0	33.6	42.0	62.0	97.4	140	185	225
150 " " " "	24.0	33.6	50.4	67.5	85.5	128.0	203.0	300	375	413	21.0	29.3	39.0	50.4	63.0	93.0	146.4	210	277	344

TABLE 8 CAPACITY AND HORSE POWER OF PIVOTED BUCKET CARRIERS

	Power House	Path	Speed per minute feet	H.P. REQUIRED RUNNING		Tons per hour
				Light	Loaded	
A	street railway	Horizontally 200 ft. vertically 110 ft. then horizontally 180 ft. and return	54	9.9	21.0	92.3
B	railroad shops	Rectangular 64 ft. horizontally and 49 ft. vertically	45	2.7	4.6	33.0
C	electric lighting company	Rectangular 152 ft. horizontally and 52 ft. vertically	45	3.3	5.0	30.40
D	department store	Vertically 114 ft. horizontally 75 ft. and return	42	6.17	15.4	40.0
E	navy yard	Rectangular 103 ft. horizontally 33 ft. vertically	46	3.0	5.0	30.0

Conveyor drives reciprocating feeder

posed, and not materially less than heavier and more cumbrous looking conveyors of other types performing equivalent service.

19 The most serious objection to belt conveyors, and the one which has prevented their even more general use, is the lack of durability of the belts, their liability to destruction from accidental causes, and the expense of their frequent renewal. Their average life probably does not exceed two to three years, in spite of the fact that there are many individual instances where they have given much longer service.

20 A further objection is the difficulty of delivering at intermediate points, which is accomplished through the medium of a rather

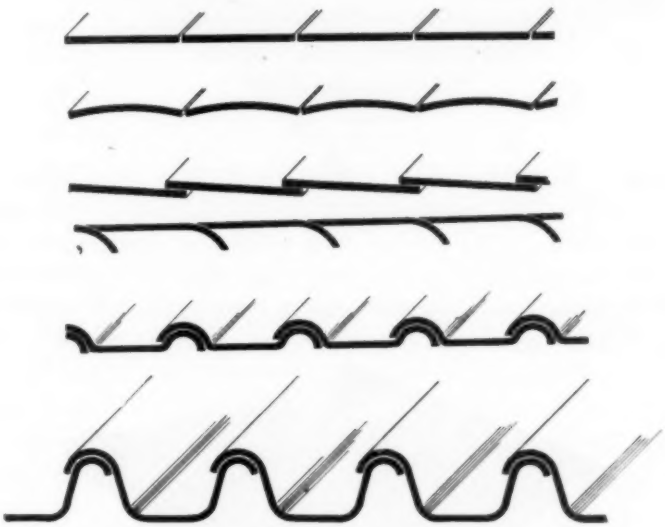


FIG. 10 SECTIONS SHOWING FORMS OF PLATFORM CONVEYORS

cumbrous and slow moving discharger. For filling long bins, however, a discharger is now used which travels slowly back and forth the length of the conveyor, its movement being automatically reversed at the ends of its path.

APRON AND BUCKET CONVEYORS

21 The most elementary form of link or chain belt conveyor approximating most nearly the belt, consists of flat steel or wooden slats attached between two chains, forming a continuous platform or

apron. The diagrams in Fig. 10 show successive modifications of this until the overlapping gravity bucket carrier is reached. Fig. 11 shows a plain, flat-top, steel apron. Where the slats are bent in arcs of the diameter of the head wheels, in passing around these wheels the scraper or chute may be placed close to the apron, thus

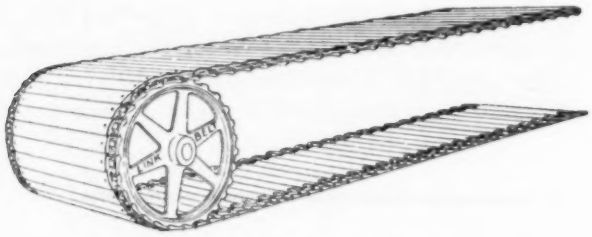


FIG. 11 ENDLESS APRON

adapting it to handle such sticky materials as clay, sugar, etc. In Fig. 12 the carrying slats are beaded at each edge, thus greatly stiffening them and increasing their ability to carry heavy loads, while the overlapping of the curved edges keeps the material from sifting through, making in this respect these carriers the equivalent

FIG. 12 BEADED SLATS

of a true belt. Fig. 13 shows this principle of construction carried still further, forming a corrugated apron, the elements of which are almost pan shape; and in Fig. 14 these have become real pans, and are adapted, as are the carriers shown by the two preceding figures, to carrying materials horizontally or at inclinations of 25 deg. to 30 deg., and to the heaviest loads.

22 None of these carriers are designed to elevate material except at an inclination, nor can they discharge except at the end of their run in passing around the sprocket wheels. Fig. 15 shows a still further evolution, this carrier, from the form of the pans, being enabled to convey on the horizontal run and also ascend vertically, delivering

FIG. 13 APRON CARRIER

the load at the top of its rise as it passes around the head wheels In the carrier shown by Fig. 16 the pans or buckets instead of being rigidly attached between the chains are suspended from them by trunnions, thus always maintaining their horizontal position and permitting them to carry their load successively, horizontally, vertically, horizontally again, or in any given path till the buckets encounter

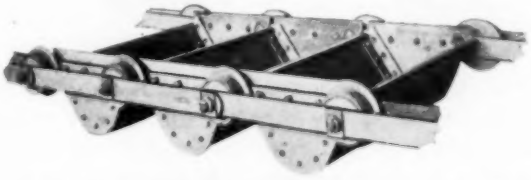


FIG. 14 FINAL DEVELOPMENT FROM APRON TYPE

suitable mechanism for tilting and discharging them at as many points as may be desired. The further step in the perfection of this type of carrier was the addition of lips to the buckets which overlap so that they may be filled without spilling between them. This lap is preferably made A-shaped to avoid the carrying of any material and its spilling at the corners where the path of travel changes, and the buckets separate.

23 The overlapping feature makes it necessary, in order that this carrier may complete its path without the effect of the action of gravity being interfered with by the locking of the lips, to provide some device external to the carrier itself to reverse the lap before it starts to ascend. In the most recent form of carrier correct action is attained by suspending the buckets from extensions of the inner chain links beyond the points of articulations, as in Fig. 16. By this means the buckets travel through a longer path than do the chains from which they are suspended, when passing around the wheel in starting to ascend, and thus automatically unlap themselves. Conveyors of this character are usually run at speeds of 30 ft. to 50 ft. per min., and where they are equipped with self-oiling rollers of 6 in. to 8 in. diameter require but very little power for their operation,

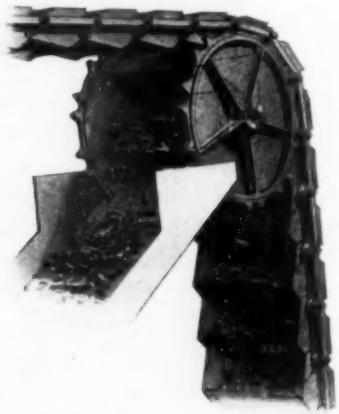


FIG. 15 ROTARY DISCHARGE HEAD

aside from the theoretical power actually required to elevate the material. Table 8 shows the capacity and power consumption of five carriers of this type.

24 Under the head of conveyors which carry their load come those which lift vertically and are known as elevators. The most elementary form consists of one or two endless strands of link-belt, rubber or canvas belt, to which are attached at intervals buckets or cups. The lower wheels are carried in a boot into which the material to be elevated is delivered, and in passing around these wheels the buckets scoop up their load throwing it out upon a chute by centrifugal force as they pass around the upper or head wheel. Friction encountered in pulling through the material in the boot and the speed necessary to get the proper centrifugal effect at the top imposes the

same limits of usefulness upon this form of elevator as upon the scraper conveyor.

25 A type of wider adaptation has continuous or actually overlapping buckets, as shown by Fig. 17. Here the material may be delivered directly into the buckets and in passing over the head the front of each forms a chute for the material in the next following bucket, so that but little centrifugal action is required and the speed may be slow. The most modern form of this elevator is shown by Fig. 18, in which the buckets are at all times in their circuit in actual contact, preventing any material from falling between them, either

FIG. 16 PIVOTED OVERLAPPING BUCKET CARRIER

at the feeding or delivery points. This is due to their attachment between their chains with the back in the pitch line, so that in passing around the wheels they assume chordal instead of tangential positions,

26 Several of the types of conveyors shown may be intentionally or accidentally loaded beyond their normal working capacity for a short time without serious results. Those which elevate as well as convey, however, are definitely limited in capacity by what the buckets can actually hold without spilling; so that some means of regulating the supply is essential to well designed machines of this class. There are various ways of doing this. Some materials, like

the smaller sizes of anthracite coal, grain, sand, etc., will maintain an even flow through a gate opening which serves to regulate the amount.

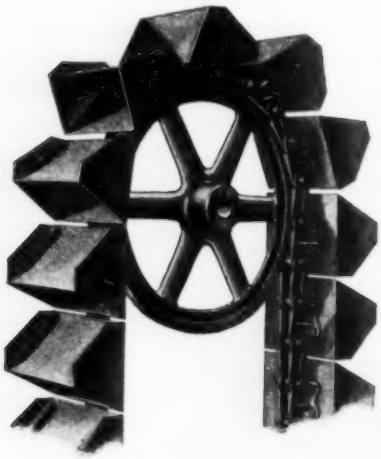


FIG. 17 CONTINUOUS BUCKET ELEVATOR

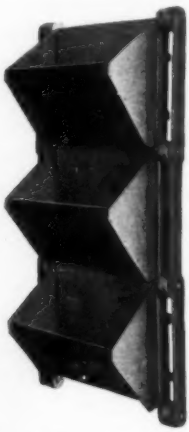


FIG. 18 OVERLAPPING BUCKETS

For the smaller sizes of soft coal, broken stone, and kindred materials a rotary feeder resembling a paddle wheel, usually with three or four compartments, is used, as in Fig. 19

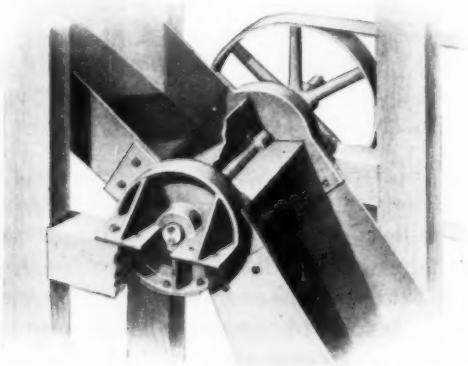


FIG. 19 ROTARY FEEDER

27 For the more coarsely broken materials, such as the larger sizes of coal, and particularly mine-run coal, the supply is regulated

by a feeding belt usually of the type shown by Fig. 12, already referred to, or by the reciprocating plate illustrated in Fig. 20. Both of these devices work beneath a hopper in which is provided an opening of sufficient size to permit the passage of the largest pieces without danger of blocking the opening, the size of this being entirely irrespective of the *quantity* of material it is desired to feed. Both types of feeders must extend beyond the natural angle of flow of the material through the opening, which thus can have no further movement, except as imparted to it by the forward movement of the feeding conveyor, or by the reciprocating movement of the plate.

MERCHANDISE CARRIERS

28 The foregoing has dealt mainly with materials handled in bulk. Many of the same devices with little or no modification will handle materials in boxes, bundles, barrels or sacks. To avoid injury to the packages, they are usually carried on moving wooden aprons attached between two chains, either sliding on ways or with rollers

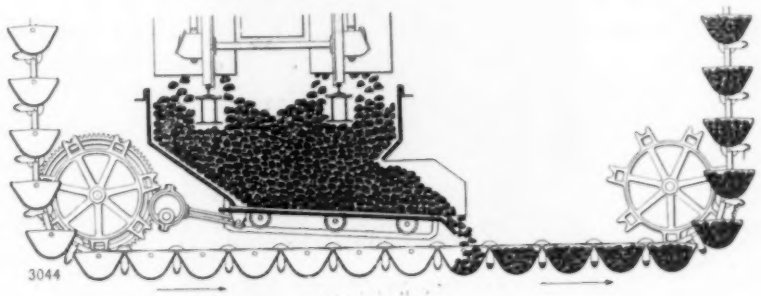


FIG. 20 RECIPROCATING FEEDER

attached if the carriers are heavy ones. Belt conveyors are also very successfully used for light loads and boxes may be conveyed long distances by running over a succession of small rollers set in frames inclined about $\frac{3}{4}$ in. per foot, gravity supplying the conveying force.

29 Packages and barrels are elevated by fingers, arms, or cradles projecting from the chains, arranged to deliver over the head, or of special design that may be tripped and deposit their load at intermediate floors. The most useful form of elevator, however, has suspended trays pivoted between two chains and free to maintain,

their horizontal position under the influence of gravity. These trays have carrying fingers which intermesh with corresponding fingers interposed in the path of the tray at the loading points, and from which they automatically pick up their load, depositing it automatically on similar intermeshing fingers interposed in their descending path at the floor where delivery is required. This form of elevator is shown by Fig. 21; it may follow any prescribed path, horizontally or vertically.

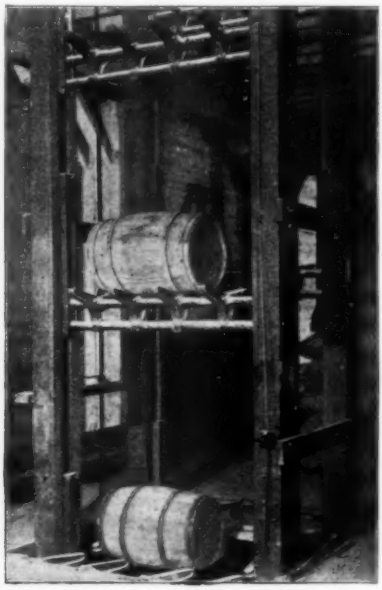


FIG. 21 FREIGHT AND PACKAGE ELEVATOR

CHAINS

30 Inasmuch as chains are an important element in most of the devices under discussion, some brief reference should be made to them. Every common type has been used for conveying purposes, and great ingenuity has been displayed in developing special forms. The present tendency, as might be expected, is towards the use of fewer types, which have demonstrated their fitness for their particular duty. For the conveyors and elevators of lighter service, the Ewart Link-Belt still prevails, or its equivalent in malleable chains with closed ends and pin connection. For double strand service, where the chains are supported, they are made with rollers, as in Fig. 22,

which shows an approved form. The rollers also serve to reduce wear on sprocket wheel tooth.

31 Fig. 23 is a type of chain, which, running in a trough, acts as a conveyor without any attachments, a modification of this having short wings cast integral with and projecting from the side bars, so as to increase the width and conveying capacity. These chains are buried

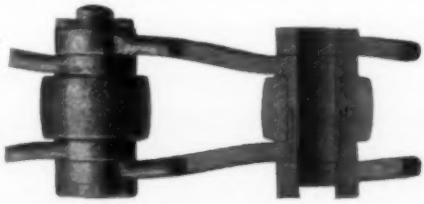


FIG. 22 ROLLER CHAIN

in the material conveyed and move it along bodily, up to a depth where the friction on the trough sides would become so great that the chain would pull through the mass instead of moving it.

32 Fig. 24 is a chain long used in two, three, four or more parallel strands for handling logs, bales, barrels, etc., the chains merely sliding, and themselves forming the complete conveyor.

33 For long runs and heavy duty, cable chains have been used, on account of their strength. It is not easy, however, to attach any-

FIG. 23 SAWDUST CHAIN

thing to them, nor does the ordinary pocket or rag wheel prove satisfactory or durable for driving. To meet both of these objections, the Dodge chain, Fig. 25, was devised, the bearing block interposed between the links at their articulation affording ample driving contact for sprocket tooth, and when cast with various attachment wings, providing convenient fastening for flights, etc. This chain also has

the advantage of permitting turns in both horizontal and vertical plane in the same conveyor.

34 To a limited extent effort has been made, particularly in long conveyors, to take advantage of the great strength with relative lightness of the steel cable, as a means for conveying, small cast blocks being clamped to it at intervals to engage the sprocket teeth and carry the flights. The lack of durability of the small individual outer strands of the cable, and the heavy tension under which it has to be run to avoid kinking, are disadvantages that have made its use quite limited.

FIG. 24 TRANSFER CHAIN, DETACHABLE

35 The "Monobar" chain, Fig. 26, has some of the advantages and avoids some of the objections to the cable. It is made up of round steel bars of high tensile strength, with malleable iron connections or sockets, providing a large articulating surface.

36 Fig. 27 and 28 illustrate a successful type of chain designed to handle such gritty materials as ashes, coke, cement, clinker, etc. Here the articulation takes place between a pin and bushing, both case-hardened and both renewable. The bushing on the outside is encased by a sleeve which protects it from contact with the sprocket

FIG. 25 DODGE CHAIN

tooth, and by making this a rolling contact, reduces wear on both chain and tooth to the minimum.

37 Chains made up of steel stamped links, with riveted or pin connection have the widest use. Where their duty is severe, and the holes in the links, as well as the pins, would be destroyed by the pressure on the articulating surfaces in passing around the sprocket wheels, the inner pair of links is connected together by a rigid bushing and the pin held rigidly in one or both of the outer pair of links.

All relative movement, therefore, must take place between the pin and the bushing, and a large bearing surface is thus obtained, without any wear coming upon the links themselves. Fig. 29 shows a typical chain joint of this kind.

38 The Maximum chain, Fig. 30, represents, perhaps, the highest development of a chain designed merely for conveying purposes.

FIG. 26 MONOBAR CHAIN

Here it will be seen that both outer and inner links have a bearing upon the pin for the full width of the chain, and it being unnecessary to secure the pin to either set of links, it is free to roll to a greater or less extent each time the chain turns around the wheels. This seems to have a densifying rather than wearing effect on the pin, and always keeps it perfectly round. In chains of this type it is not unusual to find the pins highly polished after considerable use.

APPLICATIONS OF CONVEYORS

39 As bearing on the uses of conveyors and the economy that may be effected several different applications of conveyors will be discussed and certain installations referred to.

FIG. 27 AND 28 CHAIN FOR GRITTY MATERIALS

40 The simplest application is merely to save labor expense in transporting material between given points. A conveyor, Fig. 31, handling 700 lb. glucose barrels from refinery to wharf 450 ft. distant, actually effects a very great economy—the cost of this installation, some $3000, being saved in approximately three months. As this

was installed some years ago the first cost would be much greater today, but the proportionate increase in the cost of labor would make its showing equally good.

41 Short conveyors similar to the above are used to handle merchandise between vessels and warehouse, being hinged at the warehouse floor level, so that they may be inclined upwardly or downward, according to the position of ports of the vessel, at any stage. The purpose of such an installation is to aid labor rather than displace it. Nevertheless these conveyors are incidentally money-savers. Four of them operating in pairs running in alternate directions, each 110 ft. long, saved their first cost, approximating $16 000 in one year of use.

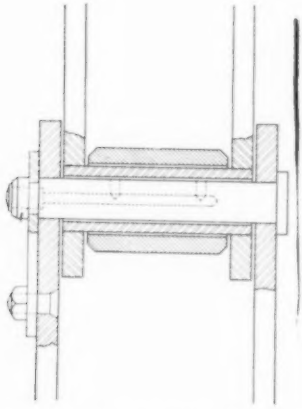


FIG. 29 SPECIAL CHAIN JOINT

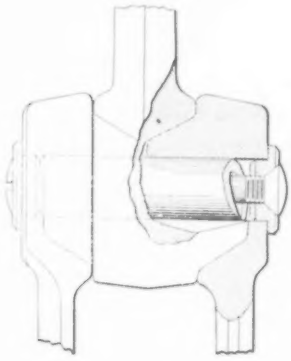


FIG. 30 MAXIMUM CHAIN

42 Elevating and conveying devices have an extended use as an adjunct to special processes where the mere conveying function is secondary. Illustrations of this are conveyors which, at slow speed, carry ores through roasting furnaces, plate glass and glass ware through annealing ovens, and various products through drying, steaming, or sterilizing chambers and tanks. Materials are also conveyed for the purpose of giving them time to cool, and slow moving apron or platform carriers are utilized for the sorting and picking of ore and coal, and for filling, sealing, and labeling canned and bottled goods.

43 The broader and more intelligent use of conveying machinery which brings it directly within the province of the engineer, is where in addition to its primary purpose, it determines or modifies the character of a plant. The accepted type of modern power house with large

storage bins above the boilers, from which the coal is drawn by spouts to mechanical stokers, is made possible by the conveyor which receives the coal from cars, boats, or wagons, outside the building, elevates and distributes it in the overhead bin; and into the returning run of which in the basement, when not handling coal, the ashes may be drawn from hoppers beneath the boilers and elevated to overhead pockets, whence they may be drawn as convenient. In such boiler rooms no coal or ashes are visible, and the same cleanliness may be maintained as in the engine room.

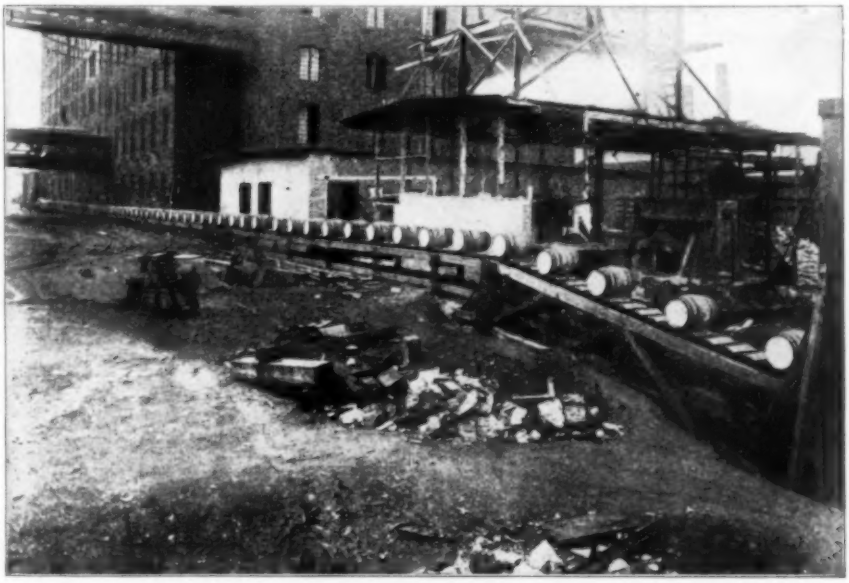


FIG. 31 FREIGHT CARRIER

44 The pivoted bucket carrier, to which attention has been called, has for a number of years been practically regarded as standard for this purpose, in the majority of cases handling both coal and ashes, but in some large power houses coal only, the ashes being taken care of by a second carrier, or by some other means. While ashes are a much more destructive material to handle than coal, largely due to their corrosive effect when wet, the cost of maintenance of these carriers is so small, even under this condition, that they are well adapted to the double service.

45 Taking as an illustration a light power plant of moderate size in New Hampshire where one of these carriers had been in use four years with no serious interruption: the annual consumption was 18-000 tons of coal per year, elevated 52 ft. and carried horizontally 110 ft. The average operation was 60 hours per week, one man looking after the carrier in connection with his other duties. The cost of repairs averaged $120 per year, or 6/100 cent per ton handled, with

FIG. 32 ELEVATING COAL TO TOP OF BREAKER AT MINE

a cost for power and attendance of 3 cents per ton, making a total of 3-6/100 cents per ton. These unit costs are high because the coal is handled at a rate very much below the capacity of the machine, and no credit in these figures is given to the tonnage of ashes handled.

46 The street railway power house referred to in Table 8 was equipped with duplicate carriers and consumed 15 000 tons of coal per month, the carriers operating about 65 hours per week, with a cost for repairs of but 1-10 cents per ton; and the machines showed

scarcely any wear. The cost per ton for power, supplies and attendance was 1-1/10 cents per ton.

47 A carrier equipped with 24 by 24 buckets at the Union Stock Yards, Chicago, with a vertical lift of 58 ft. and a horizontal run of 138 ft. has been in continuous operation since 1903 handling an average of 2500 tons of coal per week with no expenditure whatever for repairs and is still in such excellent condition that it is probable no repairs will be required for some four or five years.

48 The modern coal mine affords another illustration of plant modification. Here at a little distance from the shaft mouth is a building of great height necessary for the coal to pass through the various preparing operations of crushing, screening, picking and sorting, into the shipping pockets. Formerly the mine cars had to be elevated above the shaft to the height of the building, pushed from the cages, and hauled to the dump at the top of the building, and back to the cages. The modern practice is to dump the cars without removal from the cages, at the shaft mouth, into an inclined conveyor of great capacity which carries the coal to the top of the breaker or tipple building, permitting the immediate return of the mine cars, when dumped, to the bottom of the shaft. An illustration of such a conveyor is shown in Fig. 32. Such conveyors handle coal at the rate of 500 tons and more per hour, and similar ones used in loading vessels have successfully and frequently handled 1000 tons per hour.

49 One of the earliest of these carriers was placed in operation late in 1902 near Pittston, Pa., operating on an incline of 25 deg. and conveying the coal 355 ft. the buckets being 48 in. wide. This carrier handling 130 000 tons per month was in excellent condition after four years' use, the only repairs being the renewal of the carrying rollers, and the driving pinions of the head gearing. The cost of repairs averaged for material 4/100 cent per ton handled, and for labor 6/100 cent per ton, or a total repair cost of 1/10 cent per ton. This machine had a further record of never having caused a day's shutdown of the plant.

50 In the most advanced development and utilization of conveying machinery at the present day, it forms the basis of a complete process or system, two or three illustrations of which will be briefly referred to.

51 In a typical plant for supplying locomotives with coal, sand, and water, and for the removal and disposition of the cinders, the coal is carried in an overhead pocket of 1000 tons capacity, or from one to two days' supply. From this pocket it is drawn as required into

small scale pockets above a series of coaling tracks, so that accurate record may be kept of the amount delivered to each locomotive. While standing beneath the pocket, or adjacent to it, the cinders are raked into small trolley cars in the raking pits which are long enough to accommodate three locomotives each. These trolley cars as filled are pushed over hoppers beneath the station, from which the cinders may be drawn into a carrier running beneath them all, and finally ascending and delivering into overhead cinder storage pocket.

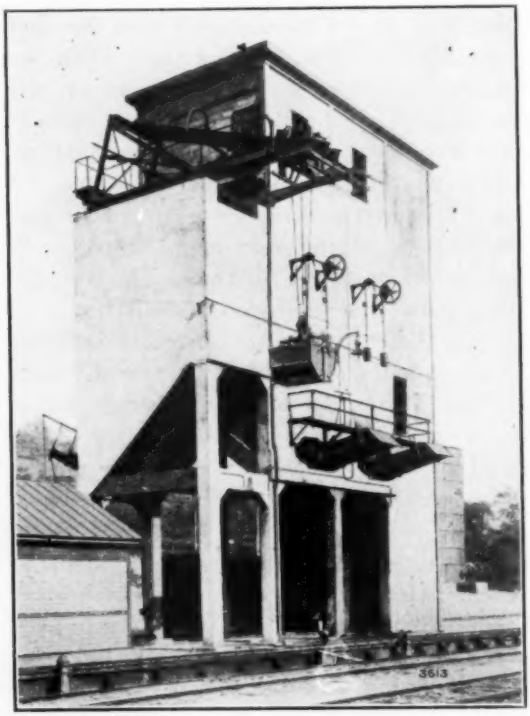


FIG. 33 LOCOMOTIVE COAL AND CINDER STATION OF REINFORCED CONCRETE.

Elevators of suitable design receive the coal and sand from supply tracks and deliver into conveyors which distribute into the overhead coal and sand pockets. As a safeguard against accident and delay, the coal receiving track hoppers and elevators are in duplicate.

52 In Fig. 33 is a locomotive coal and cinder station of reinforced concrete, built by the Link Belt Engineering Co., for the Pittsburg and Lake Erie Ry., Pollock, Pa. The capacity of the coal pocket

is 200 tons, which is supplied by a gravity discharge elevator. The latter is fed from track hopper, as shown in diagram, and delivery to boot is made regularly and automatically by reciprocating feeder. The cinder bin holds 20 tons and is served by a tub hoist of 1-ton capacity. The tub rests on a track, running in a pit under the service track and receives cinders from the fire-box while the locomotive is coaling.

53 Cost figures of fueling stations are somewhat unsatisfactory for purposes of comparison as the practice of railroads in what they charge against cost differs so greatly. Table 9 shows the cost per ton of coal handled at twelve stations located on one western road for a period of six months, these figures covering labor cost only.

TABLE 9

Station	February	March	April	May	June	July	TONS HANDLED		
							May	June	July
1	0.102	0.108	0.027	0.036	0.014	0.019	2836	3026	2807
2	0.025	0.027	0.033	0.031	0.033	0.033	1137	1058	1072
3	0.012	0.011	0.023	0.027	0.031	0.012	9063	9028	8907
4	0.017	0.016	0.020	0.029	0.029	0.026	1222	1145	971
5	0.009	0.009	0.010	0.015	0.013	0.010	4156	4308	4044
6	0.007	0.006	0.011	0.012	0.013	0.013	2330	2479	2333
7	0.011	0.009	0.010	0.008	0.009	0.011	2939	2680	2156
8	0.011	0.010	0.012	0.025	0.013	0.013	2157	1976	1845
9	0.014	0.014	0.012	0.012	0.012	0.018	2360	2448	2501
10	0.038	0.011	0.011	0.018	0.009	0.010	3808	3875	4488
11	0.017	0.014	0.014	0.017	0.020	0.041	1595	1403	1359
12	0.033	0.020	0.021	0.020	0.030	0.010	1795	1909	2355

Average cost of handling the coal at twelve stations for *A period of six months* 1¾ *cents per ton.*

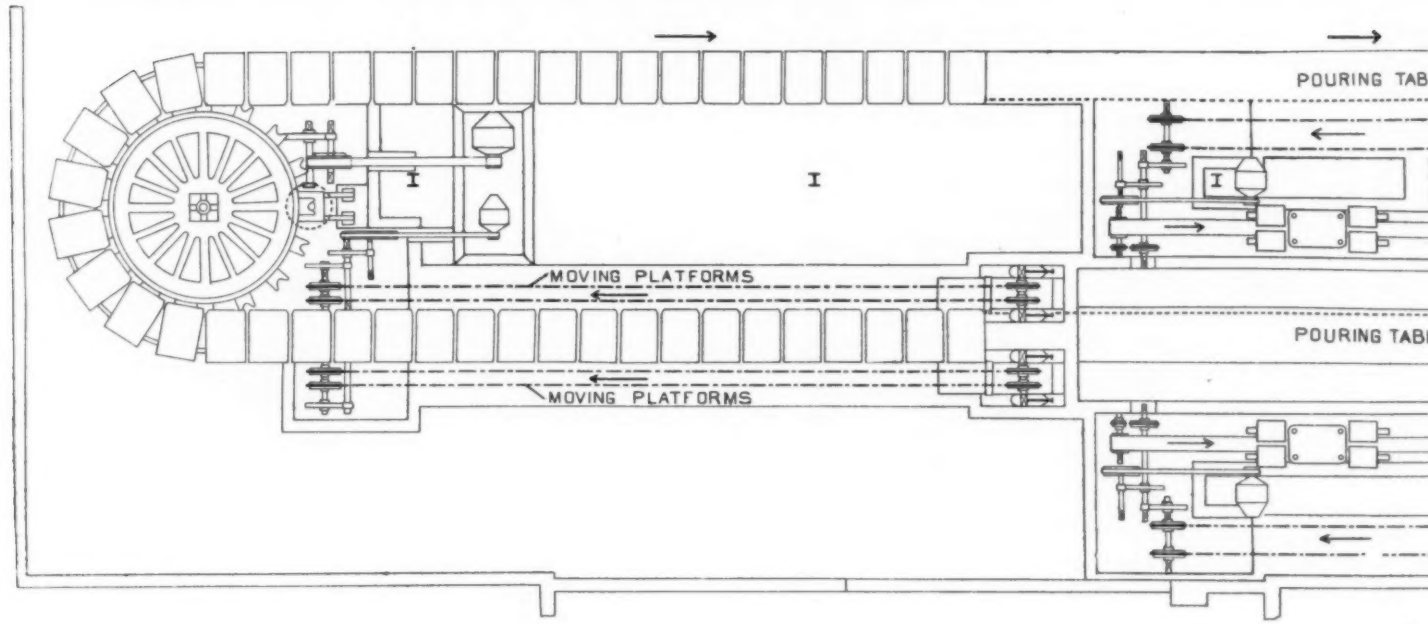
The variation is due to the tonnage handled and to the fact that while for the most part the coal is received in 50-ton self-cleaning cars, occasionally it had to be *shoveled* out of flat bottom gondola cars. Where the cost exceeds 2 cents per ton it is due to this cause. The total average shows a cost of 1¾ cents per ton.

54 Table 10 shows comparative records for one year of eight locomotive coaling stations and coaling trestles of a large eastern railroad. The average total expense for the pockets equipped with steel elevating machinery is 4.88 cents per ton; for the inclined belt conveyor type it is 9.69 cents per ton, and for the trestles 4.46 cents per ton. However, the last figure does not take into account any allow-

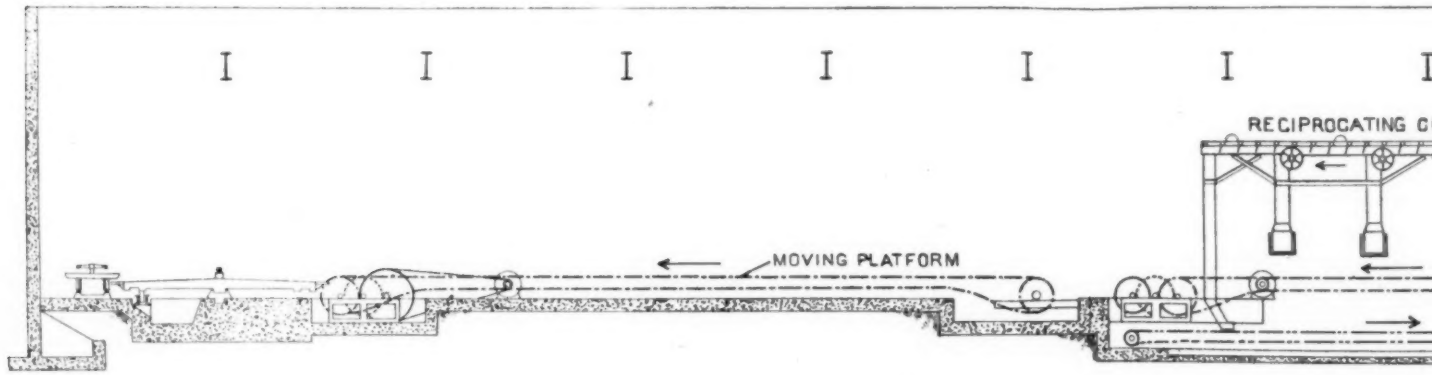
TABLE 10 OPERATING AND MAINTENANCE COSTS FOR LOCOMOTIVE COALING STATIONS FOR ONE YEAR

Type	Tons handled	REPAIRS LABOR AND MATERIAL		SWITCHING CHARGES		LABOR DUMPING COALING		FUEL FOR OPERATING MACHINERY		TOTAL EXPENSE	
		Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton
Bucket elevator	130 850	$275.48	$0.0021	$924.00	$0.0071	$4394.44	$0.0336	$826.00	$0.0063	$6419.92	$0.0491
Inc. belt conveyor	62 899	1485.97	0.0236	440.29	0.0070	3652.61	0.0581	494.00	0.0079	6072.87	0.0966
Bucket elevator	43 321	320.85	0.0074	456.25	0.0105	996.45	0.0230	378.77	0.0087	2152.32	0.0496
Bucket elevator	183 410	2415.22	0.0132	1265.53	0.0069	4536.77	0.0241	550.00	0.0030	8767.52	0.0478
Inc. belt conveyor	47 109	1456.71	0.0309	334.47	0.0071	2473.70	0.0525	316.00	0.0067	4580.88	0.0972
Trestle	110 138			813.60	0.0074	4631.78	0.0421			5445.38	0.0495
Trestle	276 397			2034.60	0.0074	8451.56	0.0305			10486.16	0.0379
Trestle	61 570			800.41	0.0130	2056.85	0.0334			2857.26	0.0464

Average total expense per ton handled—stations with inclined belt conveyors $0.0969
Average total expense per ton handled—stations with elevators 0.0488
Average total expense per ton handled—stations with coal trestles (exclusive of repairs) 0.0446

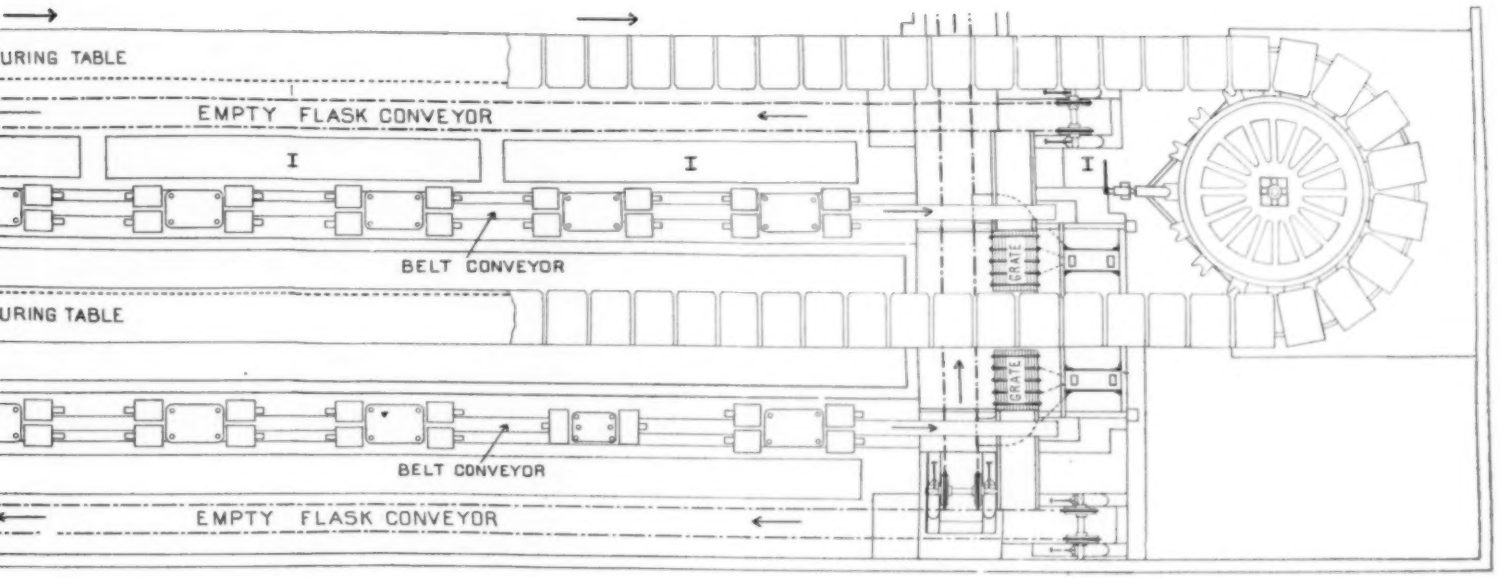


Pla

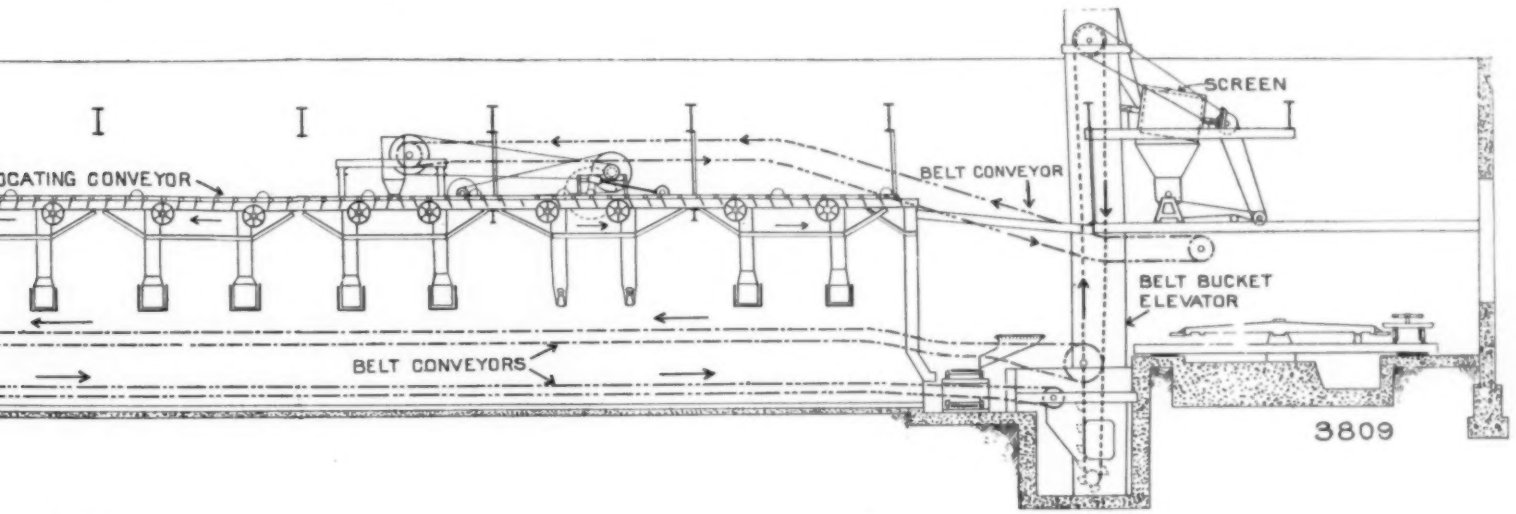


Eleva

FIG. 34 CONVEYOR SYSTE



Plan



Elevation

EYOR SYSTEM FOR MODERN FOUNDRY

ance for maintenance of the trestle. This charge will be small for the first 12 or 15 years, after which it will be considerable. The switching charges are about the same for the trestle and mechanically operated pocket. The chances for accidents to locomotives and cars are considerably greater in drilling cars on and off the trestle. The trestle, of course, has no expense for fuel. The chief difference in costs between the inclined belt conveyor stations and those with steel conveying machinery lies in the repair charges.

55 An important application of conveying machinery is the well-known Dodge system for the storage of anthracite coal. Conical piles of coal are formed by conveyors supported on shear trusses. This, now the recognized standard method for the storage of anthracite coal in large quantities, has reduced the handling costs in and out of storage, which formerly were 20 cents per ton and upwards to less than 4 cents per ton, and by making the daily output of the mines to a considerable extent independent of the demand of the moment, worked a benefit both to the operators and to labor by establishing more uniform working hours.

56 Fig. 34 shows a complete handling system of a modern foundry making a uniform product in large quantities. A conveyor, which is practically a continuous moving table, runs the entire length of the foundry. Near one end of this stand the molding machines, and a mold when made is immediately placed on the carrier, which is constantly moving at a slow speed. Near the other end of this carrier stand the cupolas, and as the molds arrive there, they are poured by men who perform no other function, the work of pouring being facilitated by the suspending of the ladles from overhead trolley rails, and by conveyors alongside the main carrier and flush with the floor, moving at the same speed as the carrier, upon which the pourers stand while pouring.

57 The returning side of the carrier is filled with the molds which have been poured, and which have time to cool. Before the molding machines are reached, the molds are automatically raked from the carrier onto screen bars, through which the sand falls. The castings slide over these bars and fall on a conveyor which takes them to the cleaning room; the flasks are lifted off and placed upon other conveyors, which return them to the molding machines. The sand, which has fallen through the grating, is caught by elevators, delivered to screens which remove lumps and sprue, passed through mixers onto cooling and tempering conveyors and is finally delivered to conveyors running above the molding machines which furnish the sand in

requisite quantities to them. So completely is the handling of all the products carried out without manual labor that the little sand "struck off" the molds before putting the two halves together is caught by small belt conveyors beneath the floor and carried to the sand elevators.

58 One of the earliest foundries to adopt this system of handling, although already having a systematic organization, and taking every advantage of highly specialized molding machinery and piecework rates, was able to effect a saving of ½ cent per pound; and very careful and conservative estimates made on the probable economy of a similar system by a foundry of large and rather a complex output, contemplating such an installation, showed that its first cost, of about $45 000, would probably be saved in 2½ years.

59 These last few illustrations of the most systematic use of conveying machinery, bring it peculiarly within the province of the engineer. In these no expense has been spared that could add to the efficiency, reliability and durability of the installations, and the economies effected thereby have been correspondingly great. While such results may not be hoped for from every installation, these may at least suggest to engineers that the subject is one that will well repay their study.

CONVEYING MACHINERY IN THE PORTLAND CEMENT PLANT

By C. J. Tomlinson, Neponset, Ill.
Non-Member

In the general expansion of industries experienced during the past few years, the larger works have presented a favorable field for the increased use of the labor saving devices for the transportation of materials. These devices are to a large extent machines that have been in use in some industries for a number of years, and in these locations, have given long and efficient service. But under the new conditions, operating under increased capacities, with heavier or more exacting duties, inherent defects develop that have been of small consequence in their former uses; and it is expedient to study this machinery with a view of deciding on a more economical or intelligent use of the same.

2 The problem of the proper form of conveying machinery is often of most fundamental importance, preliminary to the design of works involving in a measure, the cost and arrangement of buildings and the care, repair, and use of the machinery served.

3 There are a number of conveying devices in use in certain industries that have apparently given most satisfactory results, and it is therefore natural for one to resort to them for use in works that involve the conveying or elevating of quantities of loose materials. The devices referred to are: the belt conveyor, the screw-conveyor, the chain and bucket elevator, and the chain and bucket conveyor carrying or dragging the material with either buckets or flights.

4 This machinery is being tested out in the portland cement plant under conditions that are of utmost interest to engineers, involving as they do the question of the economical limit of their use.

To be presented at the Detroit Meeting (June 1908) of The American Society of Mechanical Engineers.

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5 Of these devices, the belt conveyor occupies a leading place, and it has given good results when handling grain or any material not heated, sticky, or light enough to be objectionably dusty. It makes a convenient conveyor for contractors' use as it does not require expensive supports, or much care in their erection.

6 When used in permanent constructions it should be erected on well supported rails, elevated enough above the floor to allow for convenient cleaning up under it. In finely powdered materials the amount carried over and dislodged from the face of the belt at the leading return rolls, will make it desirable for these rolls to be elevated enough above the floor to allow a noticeable heap to accumulate, before interfering with the rolls.

7 Where the conveyor is used over bins, as in cement stock houses, it is often arranged without a floor beneath the belt and with the oiler's walkway composed of a number of narrow planks, spaced enough apart to prevent a great accumulation of the spill on them. This is a somewhat slovenly arrangement, but it is such a disagreeable place to work in these galleries, owing to the dust from the tripper, that it is expedient to prevent the necessity of cleaning up as much as possible.

8 If the carrying rolls of a conveyor are properly set, guide rolls will not be needed, and, as the belt is the largest item of expense, care should be taken to prevent undue straining of it around small pulleys, by using high angle troughing rolls, or by placing them close to a foot or head pulley.

9 In the arrangement of spouts or tripper boxes, a study of the characteristics of the material carried should be made. Occasionally it occurs, as is the case with the raw material used in cement making, that it is dry and dusty; and again damp and sticky; and a spout that will deliver the damp material will be unduly destructive on the belt when the material is running dry. A pocket of the material, provided to take the wear in an angle in a spout or in a box, is particularly liable to give trouble in a sticky material.

10 The maximum angle at which a belt conveyor will elevate is largely determined by the angle of repose of the material, and also somewhat by the nature of the same; as for instance, a material containing a large percentage of spherical bodies having a tendency to roll. In order to prevent the slight jar imparted to the material through a belt by the carrying rolls, they should be spaced considerably closer on a steep incline than would be necessary on the level; and care should be taken to insure their being in good alignment.

If large diameter return rolls are used, they may be spaced farther apart than has been usual, and a distance of 20 to 25 ft. is not too great.

11 When handling a material that is very dusty, or is explosive, as for instance powdered coal, or where the head room is much restricted, the screw conveyor has given good results; but on account of the weight and grittiness of the materials handled in portland cement work, it does not give the satisfaction it has given in other industries. It has the inherent defect that it shoves or drags the material and does not carry it, and is essentially a special machine, to be resorted to only when it is evident other conveyors can not be used. The chain and bucket elevator, using a single heavy bushed chain and overlapping or continuous buckets, has been used for crushed rock, coal and clinker. It is usually a slow speed machine having a chain speed of 80 to 120 ft. per minute. The high speed centrifugal discharge elevator is more suited for lighter materials, or for contractors' use, although it has been used considerably in powdered materials or in cement.

12 When arranging the drives for several elevators and conveyors, as in a coal grinding room where storage bins are provided over the machines, an arrangement of light drives from a line shaft is impracticable. This is especially true if it is wished to take advantage of the storage space, in preventing a general shut down in case of an accident to the machinery. A study of the requirements raises the question as to the advisability of placing bins below as well as over this machinery.

13 The large amount of dust in the air of a grinding room often causes belts or ropes to give trouble. The slow speed of revolution of the various head shafts is also a factor in the simple arrangement of motors, and as far as possible it is expedient to isolate the latter in motor rooms. The small air gap of induction motors makes them somewhat unsafe in the presence of so much gritty dust, while the models with larger air gaps are expensive.

14 The use of the pivoted bucket conveyor often simplifies the arrangement of drives. These machines, as ordinarily built, can be fed, or will deliver, at any point along the upper or lower runs, and will also elevate perpendicularly, combining in one machine the elevators and conveyors required to serve a number of machines. The long links—usually 18 in.—eliminate some of the difficulties due to wear and uneven pitch experienced in the ordinary chain and sprocket drive. It is not practicable to enclose this machine in casings for use in powdered materials.

15 This type has found increased favor among manufacturers of cement, owing to its ability to handle heated material, although it has signally failed to give satisfaction in handling a product as highly heated as the clinker falling directly from the kilns.

16 The devices mentioned are continuous and automatic in operation, but present several limitations in their design. They are composed of a number of small parts and journals so placed as to be dependent on the failure of any one part.

17 They do not incorporate a means for measuring the production of each of a number of machines being served, nor will they serve in preparing a compound of materials, as in a location under a series of bins, from any of which it is desired to draw a certain proportion of material.

18 The small trucks are excessively heavy for the load they carry, and have a mechanical efficiency as proportionately low as that of the modern large size freight car is high. In view of the conditions imposed in cement manufacture I have offered reasons for advising the use of heavy skip hoists and scale, transfer cars, similar to those in use in blast furnace work.[1]

19 Such devices require buildings of increased cost, owing to the height necessary to provide storage space beneath and over the machines; and also the elevation of these bins to admit the large scale car beneath them.

20 In return they offer data for comparing performances of a number of types of machines, records of the different shifts of operatives, and an interchangeable and flexible conveying equipment that is a great aid in repairing and maintaining heavy grinding machinery that is required to run continuously, for an indefinite period.

21 As they are non-automatic they will not compare favorably with their automatic rivals when handling a moderate tonnage; but where a given system is called upon to handle 30 to 40 tons per hour and over, the smaller machines require attendants enough to balance the increased attention required by the scale cars, and the mechanical efficiency of the devices becomes a controlling factor.

[1] *Engineering News*, February 13, 1908.

IDENTIFICATION OF POWER HOUSE PIPING BY COLORS

By William H. Bryan, St. Louis, Mo.

Member of the Society

With the growth of modern power plants in number and magnitude, there has come a corresponding increase in the extent, variety and complication of their service, and the multiplicity of their pipe lines. These carry gases or liquids, varying in kind, quality, pressure, temperature, purpose and direction. The usual steam and water lines are of almost endless variety, with drains and drips to match, besides oil, air, gas, and often ammonia and brine—each subject to further special uses and sub-divisions. The situation is confusing, even to the experienced and expert attendant; what it means to the men of ordinary experience and to new men coming into the plant may be imagined. In times of emergency and excitement the manipulation of a wrong valve may not only delay the righting of things, but often adds to the confusion,and may even cause disaster.

2 It has come to be realized, therefore, that some method of quick and positive identification of pipe lines is not only desirable but is absolutely essential to insure the highest safety and efficiency of operation.

3 These facts impressed themselves strongly upon the writer some months ago when designing the power plant for a large department store in Los Angeles. Until recently it has been the custom to paint pipe lines one uniform color. Attempts at identification have been made by attaching tags to valves, a step in the right direction. Colors have been used to a limited extent in the East, but very few

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data in that direction have been available. To fit the Los Angeles case the writer worked out a color scheme, which was later published in one of the engineering monthlies[1]. See No. 6 hereinafter. Although incomplete and of somewhat limited application, it brought out considerable favorable comment, and was republished in a number of journals. One journal[2] is to illustrate a plant by reproducing the pipe lines in color in accordance with the proposed scheme. All this impressed the writer with the belief that there was need of a more comprehensive and well digested system. He therefore instituted an investigation to learn what had already been done, and has tabulated the results as follows:

4 No. 1 Bureau of Steam Engineering, U. S. Navy. Used on U. S. vessels, and on drawings for ship's files. In general a black band or coupling indicates a supply or suction pipe, and a red band or coupling an exhaust or delivery pipe. Furnished by Mr. Alfred H. Raynal, Member A.S.M.E.

5 No. 2 Designed by Westinghouse Church Kerr & Co., for the power plant of the Pennsylvania, New York and Long Island Railway Co., Long Island City, N. Y. Mr. Henry R. Kent, Member A.S.M.E., Vice President of this company, states that they use substantially the same system in all their large work, and that it has become practically standard with them.

6 No. 3 Waterside Station, New York Edison Company. Supplied by Mr. W. F. Wells, former superintendent.

7 No. 4 Waterside Station No. 2, New York Edison Company. Supplied by Mr. J. P. Sparrow, Member A. S. M. E., Chief Engineer.

8 No. 5 Boston Elevated Railway Co. Arrows are stenciled on the pipe lines showing direction of flow; also, where practicable, brief notes stating what the pipe is for. Data furnished by Mr. Jos. D. Andrews, Member A. S. M. E., Superintendent of Power Stations.

9 No. 6 Scheme prepared by the writer for the Hamburger Department Store, Los Angeles, Cal.

10 No. 7 Scheme used in Paper Mills. Furnished by Mr. E. S. Farwell, Member A. S. M. E.

11 No. 8 Scheme used by European heating engineers on plans. No information is available as to whether this plan or any others are used in the plants themselves.

12 No. 9 U. S. Internal Revenue Department, used in distilleries.

[1] *Steam*, March 15, 1908.
[2] *Factory*, Chicago.

Tabulation of Color Schemes for Pipe Lines

NO. 1 BUREAU OF STEAM ENGINEERING, U. S. NAVY

Pipe lines	Colors of pipe	Colors of bands, couplings flanges, valves, or fittings
Steam, supply	White	Black
Steam, exhaust	White	Red
Feed pump-suction (fresh water)	Gray	Black
Feed pump-delivery (fresh water)	Gray	Red
Steam pump, suction (salt water)	Green	Black
Steam pump deliveries and flushing pipes (salt)	Green	Red
Hydraulic, supply (fresh)	Blue	Black
Hydraulic exhaust (fresh)	Blue	Red
Main, auxiliary and all other drains, sounding pipes and air vents (salt)	Pink	Same
Fire service (salt)	Red	Same
Flood pipes for magazine and trimming tanks (salt)	White with red Diamond	Black
Pneumatic service	Black	Same
Ventilating supply	Yellow	Black
Ventilating exhaust	Yellow	Red

NO. 2 PA., N. Y. & L. I. RY. CO., LONG ISLAND CITY, N. Y.

Pipe lines	Colors of pipe	Colors of bands, couplings, flanges, valves, or fittings
Steam-high pressure (superheated)	White	Same
Steam (saturated)	Bright red	Black
Exhaust from auxiliary apparatus	Yellow	Same
Drips from superheated steam, including the Holly system and connection to boilers	Bright red	Same
Holly system connections from saturated steam	Bright red	Black
Low pressure drips	Yellow	Same
Blow-off	Maroon	Same
Boiler feed from pumps to boilers, including heaters, economizers and their connections	Black	Same
Fire protection system	To match adjacent structural steel	Same
All other water lines	Blue	Same
Crank case oil between engines and separators	Slate	Same
All other oil lines	Brass unpainted	Same
Air	Green	Same

No. 3 WATERSIDE STATION, NEW YORK EDISON COMPANY, NEW YORK

Pipe lines	Colors of pipe	Colors of bands, couplings, flanges, valves or fittings
Steam, high pressure to engines, boiler cross-overs, leaders and headers	Black	Brass
All other steam lines	Buff	Black
Steam, exhaust	Orange	Red
Steam, drips including traps	Orange	Black
Steam trap discharge	Green	Black
Blow-offs, drips from water columns and low pressure drips	Slate	Red
Drains from crank pits	Dark brown	Blue
Cold water to primary heaters and jacket pumps	Blue	Red
Feed water, pumps to boilers	Maroon	Same
Hot water mains, primary heaters to pumps, and cooling water returns	Green	Red
Air pump discharge to hot well	Slate	Black
Cooling water, pumps to engines	Blue	Black
Fire lines	Vermilion	Same
Cylinder oil, high pressure	Brown	Black
Cylinder oil, low pressure	Brown	Green
Engine oil	Brown	Red
Pneumatic system	Black	Same

No. 4 WATERSIDE STATION NO. 2, NEW YORK EDISON COMPANY, NEW YORK

Pipe lines	Colors of pipe	Colors of bands, couplings, flanges, valves, or fittings
Steam to turbines, boiler cross-overs, U-bends, leaders and ring header	Black	Brass
All other steam lines	Buff	Black
Steam, exhaust	Buff	Green
Steam drip lines including drip receivers, discharges to boilers, blow-downs, reducer lines and manifolds, but not risers	Orange	Black
Gravity drip discharge from manifold to receiver, from receiver to header, header to boilers and blow-downs and reducer lines	Orange	Permanent vermilion
Blow-offs, drips from water columns, and all low pressure drips, roof leaders, over-board discharges from hot well pumps	Lead	Black
All Croton water from meters to inlet nozzles for feed water heaters, water jackets, oil coolers, step bearing pumps, or to any point where water changes temperature, or mixes with other water	Dark blue	Permanent vermilion
Warm Croton, from jackets and cooling coils to feed water heaters, also hot well to pumps and f. w. heaters	Dark blue	Black
Feed water from heaters and pumps to boilers	Pompeian red	Same
Fire lines, ash hopper service, priming lines, and all other service using water from fire pumps	Permanent vermilion	Same
Cylinder oil throughout station, from barrel tanks to cylinders	Tan	Permanent vermilion
Bearing oil from overhead tanks to all bearings, small service, and can filling valves	Tan	Black
Bearing oil from all bearings and catch-alls to filter tanks, and from filters to pumps and overhead tanks	Tan	Light green
Pneumatic system	Black	Same

No. 5 BOSTON ELEVATED RAILWAY COMPANY, BOSTON, MASS.

Pipe lines	Colors of pipe	Colors of bands, couplings, flanges, valves, or fittings
Steam, high pressure	Black	Same
Steam, low pressure	Orange	Same
Exhaust steam, to floor line	Color of engine	Same
Exhaust steam, below floor line	Buff	Same
High pressure drips to Holly receiver or traps	Black	Red
Hot water returns from Holly receivers and high pressure traps to boilers	Green	Red
Low p.essure drip to traps	Orange	Black
Discharge from low pressure traps	Buff	Black
Cold feed water, to primary heaters, toilets, sinks, etc.	Blue	Same
Hot feed water, primary heaters to boilers	Green	Same
Fire service	Red	Same
Salt water intake	Slate	Black
Salt water discharge	Slate	Red
Cylinder Oil	Yellowish brown	Black
Engine oil	Yellowish brown	Red
Air	White	Same
Gas	Slate	Same

No. 6 HAMBURGER DEPARTMENT STORE, LOS ANGELES, CAL.

Pipe lines	Colors of pipe	Colors of bands, couplings, flanges, valves, or fittings
Steam, High and medium pressure	White	Same
Low-pressure heating lines	Aluminum bronze	Same
Exhaust lines	Gray	Same
Water, pure, drains from high-pressure and exhaust head drips	Pink	Same
Impure drips, overflows and boiler blow-offs, to blow-off tank	Black	Same
From city mains or deep well, and general house distribution	Light blue	Same
Iced drinking water lines	Dark or navy blue	Same
Returns from heating system	Aluminum bronze	Same
Boiler feed	Bright red	Same
House supply (hot)	Maroon	Same
Sprinkler lines including tank, excess pressure, and draining system	Blue	Same
Oil, lubricating system	Light brown	Same
Boiler supply, fuel	Dark brown	Same
Air, vacuum heating and house cleaning lines	Light green	Same
compressed	Dark green	Same
Refrigerating, ammonia, gas	Yellow	Same
Ammonia, liquid	Bronze	Same
Brine	Orange	Same

No. 7 SCHEME OF E. S. FARWELL FOR PAPER MILLS

Pipe lines	Colors of pipe	Colors of bands, couplings, flanges, valves, or fittings.
Steam lines	White	Same
Cold water	Black	Same
Sprinkler lines	Red	Same

No. 8 EUROPEAN HEATING ENGINEERS

Pipe lines	Colors of pipe	Colors of bands, couplings, flanges, valves, or fittings
Steam, high pressure	Carmine	Same
Steam, low-pressure	Orange	Same
Steam radiators	Blue edge filled with green	Same
Direct-indirect radiators	Blue edge filled with yellow	Same
Return steam	Dark green	Same
Overflow	Brown	Same
Cold water supply	Violet	Same
Hot water flow	Sienna	Same
Hot water return	Blue	Same
Hot water radiators	Blue edge filled with blue	Same
All iron parts, such as boilers, doors, stairs, engines, blowers, dampers, chains, registers, heating pipes, traps, expansion tanks, etc	Blue lines	Same
Fresh cold air	Light green	Same
Fresh warmed air (warm air chambers)	Carmine	Same
Mixed air (warm and cold)	Yellow	Same
Vitiated air (ventilating flues)	Blue	Same
Circulating or reheated air	Violet	Same
Air vent pipes	Blue	Same

No. 9 U. S. INTERNAL REVENUE DEPARTMENT: FOR DISTILLERIES

Pipe lines	Colors of pipe	Colors of bands, couplings, flanges, valves, or fittings
Mash or beer	Red	Same
Low wines, back into still or doubler	Blue	Same
Spirits from still to cistern	Black	Same
Water	White	Same

13 Correspondence conducted by the writer with leading power plant engineers throughout the country indicated the practically unanimous opinion:

a That a uniform system would be of decided advantage.

b That it should if possible be made standard, so as to be universally acknowledged and adopted.

c That the time was ripe to enlist the good offices of this Society toward the bringing about of uniform practice.

14 There can be no question as to the value and convenience of such a system. To the extent that similar ideas have already been adopted they have proved of decided advantage. The operating force is better able to operate and maintain the plant. Action is quicker, mistakes fewer, and repair bills less. When a particular color, or combination of colors in a pipe system always means the same thing, in all plants, and under all conditions, substantial progress will have been made. To change engineers will then mean no disorganization of the force, no interruption of the service, hardly a drop in its efficiency. When such a color scheme has once been thoroughly learned, possibilities of error are largely at an end unless a new scheme must be learned with every new plant. Important as it is for the attendants, it is even more so to visiting or supervising engineers, or inspectors, making their regular rounds, whether for governmental or insurance purposes.

15 It would seem desirable for such a general scheme to meet the following conditions:

a It should be suitable for power houses of all kinds and sizes, electric, water, isolated, manufacturing, refrigerating, etc.

b It should follow existing systems as far as can be done consistently, so as to reduce confusion.

c It should use the colors which have already come to be associated in our minds with the various classes of service, such for instance as white for steam, blue for water, red for fire protection, brown for oil, etc.

d It should be as simple as possible.

e The colors should be of such a character as not to fade under working conditions. They should withstand the effects of heat, water, and ordinary use and abuse. Established trade names should be used.

f Incidentally there should be some attention to harmony of color, and to the practicability and ease of reproduction in printed charts.

g The system should if possible be one which could be used on drawings to be filed away for future reference.

16 The means of identification are many and easy. Not only are there the primary colors, but there are two or more shades of each. Furthermore, almost endless variety may be secured by giving the bands, couplings, flanges, valves, and fittings a different color from the pipe. It would seem desirable to distinguish between supply and delivery pipes as is done in the Navy. This could easily be accomplished by using a light shade of the pipe color for the former, and a darker one for the latter. At least two coats of paint should be applied, on the surface of the finished covering, or on the bare pipe when uncovered—this, of course, after the constructing and testing are complete. Arrows showing the direction of flow should be stenciled on the pipe at frequent intervals. Also in very complicated systems, a brief scheme of lettering indicating the pipe's purpose.

17 Such a system to be reasonably complete, should cover the following kinds of service:

STEAM

High pressure (100 lb. and over) saturated
High pressure (100 lb. and over) superheated
Medium pressure (under 100) saturated
Medium pressure (under 100) superheated
(Each of the above might be further subdivided as between main and auxiliary engines.)
Low pressure (about atmospheric pressure), for heating, drying, etc.
Exhaust, main, to condenser
to atmosphere
auxiliary to condenser
auxiliary to atmosphere

DRAINS, DRIPS, ETC.

From saturated steam lines to trap or Holly receiver
From superheated steam lines to trap or Holly receiver
From trap or Holly receiver to boilers
Low pressure or gravity
From trap to heater or hot well
Blow-offs from boilers, heaters, etc., to blow-off tank
Over flows from heaters, hot wells, blow-off tanks, etc.
From crank pits
House and roof drains

WATER—COLD

Supply, city or other external
Well, cistern, river, lake or other alternate
Salt
(Above from inlet, meter or other source to point where temperature changes, or where it mixes with other water, to primary and secondary heaters, jacket pumps, etc.)
Cooled from cooling towers
Hydraulic supply, under pressure, for elevators or other power service
Discharge from same
Cooling, to engine bearings
Iced for drinking throughout building
Domestic, to lavatories, sinks, etc.
Fire or sprinkler lines, including tanks, filling and drain pipes
Flood pipes for magazine or trimming tanks
Salt water discharge

WATER—HOT

From hot wells and heaters to economizers and boilers
Returns from bearings to hot well and heater
Circulating water, condenser to air pump
Circulating water, pump to cooling tower
Air pump discharge to hot well
Overboard discharge from hot well pump
Domestic, to lavatories, sinks, etc.
Flow, for house heating system
Return, from house heating system
Return from steam heating system

OIL

Cylinder, to high pressure cylinders
to low pressure cylinders
to auxiliaries
Engine, to bearings
from bearings
Crank case
Fuel, to boilers

AIR

Compressed for pneumatic tools, cleaning, pumping water, dry lines of sprinkler system, etc.
Low pressure, for pneumatic tube, cash or parcel systems, etc.
Vacuum for dust cleaning, air removal from radiators of heating systems, etc.
Ventilation, fresh cold
Ventilation, fresh warm

AIR-CONTINUED

Ventilation, mixed
Ventilation, vitiated
Ventilation, recirculated

GAS

Artificial, for illumination
for power
Natural

REFRIGERATION

Ammonia, liquid
Ammonia, gas
Brine

18 The writer had intended to work out a new and tentative scheme along these lines, for consideration with this paper. On further reflection, however, he concluded that to do so at this time would simply add to the existing confusion. A plan developed after a more exhaustive study, with the coöperation of the members of the Society, and perhaps at the hands of a special committee, would be more permanently satisfactory. The writer ventures to suggest to the profession the advisability of deferring the coloring of pipe lines, and particularly the working out of additional schemes, until the matter has had the more extended study which it is hoped this paper may aid in bringing about.

COMPARISON OF SCREW THREAD STANDARDS

AMASA TROWBRIDGE, HARTFORD, CONN.

Member of the Society

The accompanying diagram is submitted to show what is possible or impossible in combining the present recognized standards for screw threads. The United States Standard thread has long been considered too coarse for diameters of $\frac{3}{8}$ in. and smaller. The dash and dot curve of the diagram is for the Pratt & Whitney standard thread for machine screws and is substantially what most shops use for screws having diameters in fractions. As this standard nearly coincides with the standard recommended by the Machine Screw Committee of The American Society of Mechanical Engineers, which gives better and more uniform proportions, it should be discarded wherever possible in favor of the latter. Likewise, it seems advisable to stop the United States Standard at a diameter of $\frac{7}{16}$ in. instead of at a diameter of $\frac{1}{4}$ in., following the new standard of the Committee of the A. S. M. E., for sizes below $\frac{7}{16}$ in. diameter and inserting suitable extra sizes in this new standard to care for such fractional sizes as are not at present included in it.

2 It is apparent from the figure that the United States Standard is better from $\frac{7}{16}$ in. up than the A. S. M. E. sizes, hence there is nothing to be gained by continuing the latter above this point.

3 To manufacturers of parts or accessories for automobiles, the problem of using the standard of the Association of Licensed Automobile Manufacturers presents itself. Inspection of the diagram shows that this standard is not adapted for combining with the other standards. Also, while it is undoubtedly very good for use where excessive

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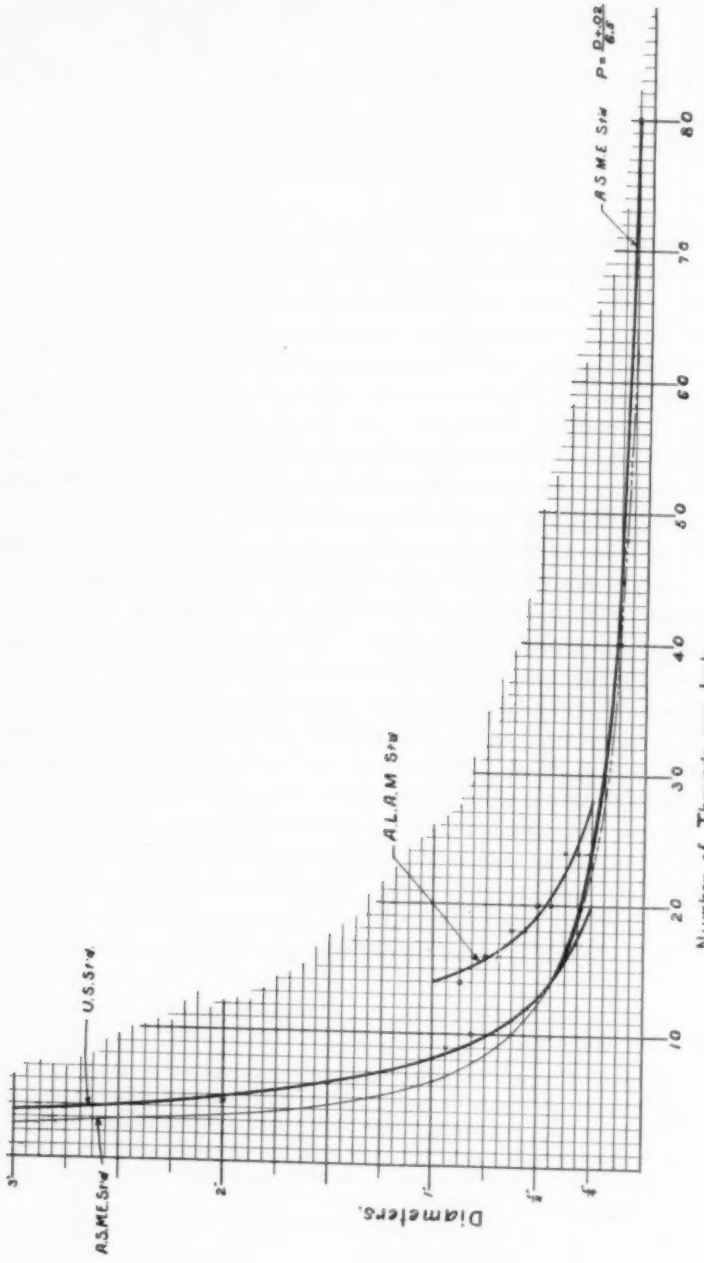

FIG. 1 COMPARISON OF SCREW THREAD STANDARDS

vibration is encountered, it is not suitable for general use. The Veeder Manufacturing Co., Hartford, Conn., furnishes nearly all the odometers used on automobiles and at the same time manufactures largenumbers of counters for use on machinery, and they have had to consider all these standards. This graphical presentation herewith was used to study the problem and as it may be of service to others, it is brought to the attention of the Society.

POWER PLANT OPERATION ON PRODUCER GAS

By Godfrey M. S. Tait, New York

Associate Member of the Society

The gas producer consists essentially of an apparatus arranged for the partial combustion of carbon, which result is achieved by means of a deep fuel bed, so arranged that while the free air is admitted to one side of the fire, allowing complete combustion in the first zone, the suceeding zones, containing carbon heated by radiation and convection, are utilized for the reconversion of the CO_2, back into a combustible gas by its coming in contact with the incandescent fuel, which is so arranged that no free oxygen has access to this part of the fuel bed.

2 Producers may be divided into three classes; the up-draft pressure producer, the up-draft suction producer, and the down-draft producer, either suction or pressure, to which may also be added a combination of these types especially designed for bituminous fuel, in which both the up and down drafts are either used alternately or in combination for the purpose of fixing the volatile hydro-carbons encountered when using this type of fuel.

3 The up-draft pressure producer, which is perhaps the oldest and most familiar type, is well known in its application for supplying a fuel gas for furnaces. This producer is usually used by steel works, glass works, and other industries requiring large volumes of fuel gas for direct burning, and consists essentially of a vertical chamber lined with refractory material, the lower end of which is immersed in a water pan, so that the water contained therein forms a liquid seal, which prevents the escape of gas at that point. This type of producer is generally designed without any form of grate (although the

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use of a grate does not affect the principle), a pile of ashes in the lower part supporting the fuel bed, and the draft being supplied through a central tuyere to the fuel.

4 This blast usually consists of a mixture of steam and air under pressure, which is obtained by means of a steam jet blower, and the gas so obtained, consists of a mixture of H, CO, CO_2, N and CH_4, the amount of the latter depending upon the nature of the fuel employed.

5 The gas thus generated, while answering all the requirements of the furnace is, due to its uncertain and varying composition, somewhat difficult to utilize for the operation of gas engines, for the reasons that will be noted later.

6 The suction producer is practically the same apparatus, although usually supplied with a grate, instead of a water seal, and has its draft induced instead of forced, as in the former type. This style of producer has so far been used successfully for power purposes, the engine itself usually supplies the necessary suction, and by means of steam or water vapor regulating apparatus, a fairly uniform quality of gas is obtained.

7 The third type, or down-draft producer consists in a reverse of the foregoing, the draft being admitted above the bed from the same orifice or similar orifices as those used for supplying fuel, the object being the fixation of the volatile hydro-carbons contained in the fuel employed, by causing them to pass off through the incandescent bed of fuel in the producer.

8 To these types may be added various arrangements of the foregoing in which combinations of up and down drafts are utilized for the double purpose of keeping the fuel beds in a well broken up condition, and for the purpose of generating special qualities of gas, such as "alternate" water gas and air gas.

9 Unfortunately the utilization of these plants in this country has been attended with considerable difficulty, due to the unsatisfactory nature of American fuels, high in fusible ash.

10 To explain this point, it will be noted that the producer business in Europe has reached a very much more advanced stage than in this country, and upon investigation it was found that this was almost entirely due to the fact that the European coals employed have very little if any fusible ash, and a very high percentage of fixed carbon which enables the operation of these plants at a rate of gasification per square foot of inside diameter entirely out of the question in this country, as the temperatures so obtained would fuse our ashes into a regular slag.

11 But for the question of fusible ash, it would be very much more advantageous, as has been found in Europe, to operate producers at a high rate of gasification, as by so doing, the temperature of the complete combustion zone may be maintained well above 2000 deg. fahr., with the result that all steam fed to the producer, even at fairly low loads, will become dissociated, and will supply a hydrogen constituent to the gas, directly proportionate to the amount of steam fed into the producer. This being the case, it was only necessary to design a steam or water vapor regulating apparatus of a sufficiently automatic nature to take care of all variations in load, to enable the plant to generate a gas containing a fairly uniform amount of hydrogen.

12 However, all attempts to obtain the same results in this country have failed, for the reason that in order to obviate troubles from clinkers, due to the high percentage of fusible ash in American fuels, it was found necessary to make the grate surface very much larger per horse power than was the case in foreign practice, and while this change practically obviated clinker troubles, we found ourselves confronted with an even worse difficulty, due to the fact that on half or quarter load, the temperature of the combustion zone in the producer was very much below the point necessary for complete dissociation of the steam supply for the producer. This gave us a gas which from five thousand or more analyses which the writer has made, showed considerable variation, the hydrogen constituent varying anywhere from 5 to 20 per cent by volume of the gas generated according to the temperature of the combustion zone in the producer, which in turn was absolutely controlled by the amount of load on the plant.

13 Of course these defects were not recognized immediately, and it took several years of practical experience to demonstrate that it was a physical impossibility to generate a producer gas under European methods in America and to have the hydrogen constituent of the same remain uniform at varying loads.

14 While this variation in the hydrogen constituent was of comparatively little moment, when the operation of furnaces with gas was considered, on the other hand it produced a very serious defect when using this gas for the operation of engines. Not so much for the reason that the total British thermal units changed, because such change was slight, and should have been handled by the governors on the engine, but that as hydrogen burns approximately twice as rapidly in an engine cylinder as carbon monoxid, and as the ignition point was usually set to conform with the ignition period of the more

rapidly burning constituent hydrogen, it followed that when this constituent fell off in quantity, that the engine would be firing at too late a period of the stroke to be economical, in addition to the fact that the late fire caused excessive heating of the exhaust valves.

15 Having obtained this information, the writer then set about to obtain if possible some other means of producer operation, so as to eliminate the most changeable constituent of the gas, namely hydrogen, having by this time become thoroughly convinced that it was more essential that an engine should have for its operation a gas with an *absolutely fixed ignition point*, than it was to supply that engine with a gas of *high heat value*, and having come to this conclusion, a series of experiments were made with a view to determining if possible a remedy for the difficulty.

16 A producer was equipped with a draft supply consisting of pure air alone, and yielded a gas consisting essentially of carbon monoxid and nitrogen, with only a slight percentage of hydrogen corresponding to the hydrogen constituent of the fuel employed.

17 This gas had a British thermal unit value of about 105, which was of course very much lower than would have been the case had the usual steam saturated draft been employed.

18 On the other hand, although having a lower heating value, the fixed ignition point of the gas and its uniformity of composition was very striking, and but for the fact that the producer, in the absence of any draft diluent became overheated to such a degree as to cause clinkers from the fusible ash in the coal, very satisfactory results would have been obtained.

19 This gas was washed and scrubbed in the usual manner, and used for the operation of a 100 h.p. three-cylinder-vertical-engine of well known make, and the remarkable fact was noted that this engine, which had formerly given great trouble from premature ignitions at certain loads while operating on regular producer gas, in this case operated with complete smoothness, and what was perhaps more surprising still, by an advance of the igniters to the correct position, it developed horse power slightly in excess of its builder's rating.

20 This apparent increase of power, however, was undoubtedly due to the fact that with this very uniform gas, which had a fixed high limit, it was possible to set the ignition at exactly the correct point, which point remained absolutely constant, barring changes due to the action of the throttling governor under load variations.

21 After making a short run under these conditions, it was found possible by increasing the compression of the engine to 200 lb., com-

bined with setting the igniters at exactly the right point, to carry about 15 per cent more power on the engine than the builders cared to guarantee. In other words, it was obvious that the builders of producer gas engines, knowing the variable quality of the ordinary producer gas upon which their engines have to operate, are very conservative in their engine ratings, as they have to be, in order to be on the safe side when the ignition point in the gas changes.

22 This and other similar experiments proved that the most essential feature in a power gas is its uniformity of composition, which in turn means its fixed ignition point, and that no matter how low the British thermal units within reasonable limits, it is perfectly possible to operate the gas engine successfully, provided that the ignition point always remains the same, it being obvious that the throttling governor on the engine would merely open wider for the leaner gas and take in more gas per stroke.

23 After settling this fact thoroughly by continued experiments the writer then looked about for some means of cooling the fire to take the place of the usual steam saturated draft, and finally decided that the use of carbon dioxid in fixed amounts might answer the purpose.

24 The exhaust from the engine was piped back with a by-pass to a mixing valve on the producer, so arranged that part air and part exhaust could be admitted to the ash pit. With a proper mixture of exhaust and free air the producer could be operated at a sufficiently high temperature to make gas, while at the same time, low enough to obviate any dangers of clinkers of the fusible ash.

25 Reference to Fig. 1 will show an elevation of a complete producer and engine plant of this kind which was installed in Brooklyn about eighteen months ago. The plant consists of (1) a gas producer of the suction type equipped with the usual type of coal feeding hopper but having no evaporator or other vapor supply needs; this producer is supplied with the usual down take pipe (5) communicating with a two-way valve (8) for throwing the purge pipe into operation when the plant is shut down, scrubber (11), purifier (12) and gas pipe (13), which in this case delivers gas to the automatic exhauster (14), a piece of apparatus which will be described later. From here the gas flows through pipe (18) to the two engines shown. The exhaust from these engines passes off through pipes (21) and (21′) to the exhaust main (22), which leaves the building at a point under the producer and is by-passed through pipe (7) up to the mixing valves (6) and (7), where air and exhaust gases enter the base of the producer.

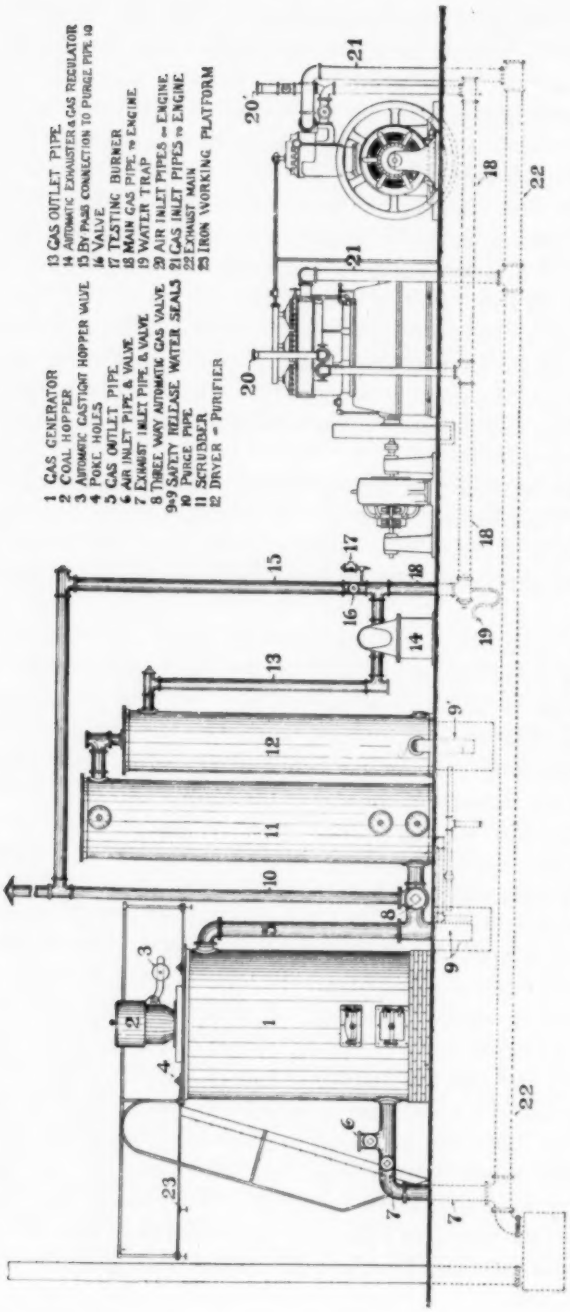
1 GAS GENERATOR
2 COAL HOPPER
3 AUTOMATIC GASTIGHT HOPPER VALVE
4 POKE HOLES
5 GAS OUTLET PIPE
6 AIR INLET PIPE & VALVE
7 EXHAUST INLET PIPE & VALVE
8 THREE WAY AUTOMATIC GAS VALVE
9-9 SAFETY RELEASE WATER SEALS
10 PURGE PIPE
11 SCRUBBER
12 DRYER = PURIFIER
13 GAS OUTLET PIPE
14 AUTOMATIC EXHAUSTER & GAS REGULATOR
15 BY PASS CONNECTION TO PURGE PIPE 10
16 VALVE
17 TESTING BURNER
18 MAIN GAS PIPE to ENGINE
19 WATER TRAP
20 AIR INLET PIPES to ENGINE
21 GAS INLET PIPES to ENGINE
22 EXHAUST MAIN
23 IRON WORKING PLATFORM

FIG. 1 ELEVATION OF PRODUCER AND ENGINE PLANT

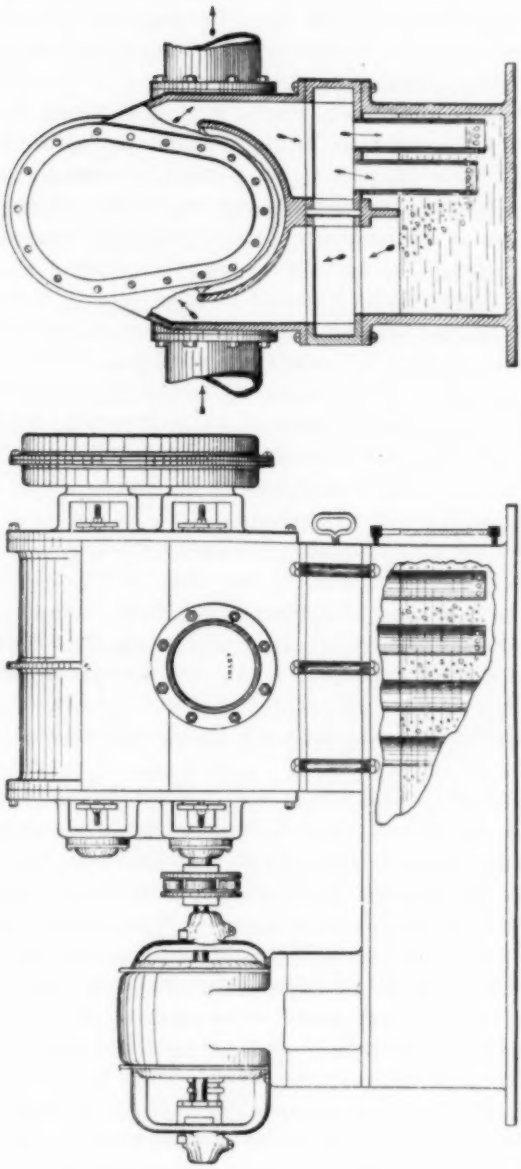

FIG. 2 TAIT AUTOMATIC GAS REGULATOR

26 The apparatus (14) of which a cut is also shown in Fig. 2 consists of a positive type exhauster operated by motor or other suitable means, and which draws the gas from the producer as indicated by the arrow points, and discharges the same toward the engines and at a predetermined and absolutely fixed pressure.

27 This pressure regulation is very simply obtained, by the fact that the outlet of the exhauster communicates through several pipes, as shown in the drawing, to a seal of water contained in the base of the apparatus, this seal of water being set to the desired point to give best results at the engines. Any excess gas over and above this pressure naturally bubbles up through this water seal, returning to the inlet side of the exhauster. This apparatus in a very simple manner takes the place of the usual gas holder and enables engines to be operated in parallel from the same suction producer.

28 This apparatus is not an essential part of the experiment above alluded to but it was found to greatly assist in steadying up the conditions upon which the plant operated and was absolutely necessary to close regulation when it was desired to operate more than one engine from a single suction producer.

29 The plant of which Fig. 1 is an illustration has now operated for about eighteen months, part of the time twenty-four hours per day, six days a week, and at loads varying from one-quarter to ten per cent above builder's rating, and has during that entire period given no trouble from variations in the quality of the gas, such as would have been encountered, had this gas been generated in the usual manner and containing the usual fluctuating amount of hydrogen.

30 Furthermore it was ascertained in practice that the exhaust pressure in the ash pit was just sufficient to offset the suction caused by the gas being drawn off the producer, with the result that the poke-holes on top of the producer could be opened and kept open without any gas escaping or any air getting into the producer, and for this same reason it was found possible to open the ash pit and grate bar doors wide and to clean the fires thoroughly while the full load was on the engines, without in any way interfering with the quality of the gas. This latter point proved to be a very satisfactory one with the operators of the plant, as it enabled them to clean their fires while the daily run was going on and no overtime had to be charged to this operation. Also the pulsation of the exhaust gave a very beneficial shaking action upon the fuel bed in the producer and seems to entirely obviate the tendency for fissures to form in the fuel bed, with the

result that the average carbon dioxid obtained in the producer gas made under this arrangement is only 1½ per cent, which, compared with the average obtained under the old method of producer operation, shows a very great saving.

31 While from a thermal standpoint it is a doubtful question whether the producer itself is as efficient a converter of heat values, under this system, as when using a steam saturated draft under test conditions, it has been found in actual practice that the fuel saving on the plant is considerable, due to the fact that the entire absence of necessity for rebuilding the fire at any time and the ability to operate continuously, naturally conserved the fuel consumption to a remarkable degree. In fact, the actual coal consumption on this plant, taken for a period of six months, and including all standby losses, showed that the plant is burning 1¼ pounds of coal per brake horse power per hour, while the load factor was less than two-thirds, and the working day but ten hours, while Sundays the plant was shut down. Further, when the occasion arose to operate this producer 24 hours per day at full load, it was found that the coal consumption was 0.7 lb. per brake horse power developed during time of operation, and that this economy could be maintained for as long a period as the load conditions allowed.

32 For operation on anthracite fuels, the up-draft suction producer shows by long odds the best economy, as it eliminates all leakages of gas while operating, which losses, in addition to the heat value thrown away, mitigate greatly against the plant by annoyances to the operators from the gas poisoning entailed, it being a physical impossibility for the operator of a producer plant to do justice to his work when suffering from a splitting headache, such as is too often the case with men employed around pressure producer plan.

33 The suction producer, on the other hand, is extremely simple of operation and does not pollute the air of the producer room to any noticeable extent, with the result that the operators take a great interest in the plant and a pride in keeping it up to the best possible working conditions. This is a point to which owners of producer plants have hitherto given very little attention and which seems to the writer to have a necessarily vital effect on the success of the enterprise.

34 Some difficulty has been found in using a suction producer where a very fine coal, such as No. 2 Buckwheat, is employed, due to the difficulty of pulling the draft through the heavy fuel bed, but the writer has found this to be merely a question of grate design and

draft distribution, and one which can be ably taken care of, if the engineer laying out the plant gives the matter its merited attention.

35 As to operation on bituminous fuel, the up-draft producer is very much easier to handle than the down-draft, but it of course involves the use of some form of tar washer to take care of the by-products left in the gas after they leave the scrubber, and as these by-products sometimes represent a considerable percentage of the heating value of the fuel employed, this type of plant is open to objections.

36 The down-draft producer, on the other hand, while it "fixes" the gas to quite a considerable extent, is subject to the tremendous disadvantage that the fine particles of ash form in the upper zone and passing downward in the fuel bed with the draft, tend to clog up the entire fuel bed, so that it is impossible to operate this type of plant for any considerable period without breaking up the fuel bed, either mechanically, or by means of a reverse blast of considerable pressure, either operation necessitating a change of conditions and gas output, calling for the installation of a duplicate unit or a large gas holder to steady the output during these periods.

37 It seems to the writer that the ideal way out of the difficulty would be to use a gas producer combining the merits of both, as far as possible, and this might be obtained by using an up-draft producer in which the outlet gas pipe protruded into the fuel bed down to within, say, three feet of the grate, and the space above the end of this pipe up to the top of the producer being filled with fuel.

38 Some such arrangement as this was tried by the writer, with the result that a gas very high in CH_4 was obtained, due to the fact that the upper half of the producer acted as a destructive distillation retort, while the lower part was only called upon to operate on the coked fuel.

39 There is of course nothing original in this idea, it having been tried in Europe in several instances, but it would seem that some such arrangement, in conjunction with a mechanical tar separator of small dimensions, would be found to go a long way toward handling the bituminous fuel satisfactorily.

40 In conclusion the writer has the pleasure to report that the gas producer business is now advanced so far toward a successful conclusion, that absolute uniformity, reliability, and continuity of operation can now be guaranteed and supplied, while at the same time, the very attractive economies always claimed for producer plants still remain, and barring the possible high first cost of the installation, there is no longer any reason why this type of power plant should not meet with all the requirements of the manufacturing industries.

AIR LEAKAGE IN STEAM CONDENSERS

A PLEA FOR SCIENTIFIC CONSIDERATION OF THE SUBJECT

By Thomas C. McBride, Philadelphia

Non-Member

Experience has shown that the presence of a small amount of air in a steam condenser has a marked effect upon its capacity and efficiency. In spite of this no serious attempt seems to have been made to determine quantitatively the amount of air mixed with steam in ordinary practice, nor definitely to define or limit this amount to exact figures in condenser contracts and guarantees.

2 If it can be demonstrated that

(a) The greater part of the air coming to condensers is the result of air leaks, and

(b) That these leaks are mostly in the prime mover and its connections and likely to be but small in amount in the condenser itself, due to the difference in the character of the two structures;

and,

(c) If it is possible to devise some convenient method of estimating the proportions of the air to the exhaust steam required to be handled by the condenser,

then, it is only as fair to expect that purchasers' specifications shall at least limit the amount of air to be handled by the air pump, that the manufacturer may intelligently select the size of this pump, as it is to expect these specifications to state the amount of steam to be condensed, that the manufacturer may properly determine the size of the condenser.

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3 In view of the one-sidedness of the usual purchaser's specifications in this regard, it is not surprising to find the manufacturer in turn exacting a condition in his proposal that the prime mover and its piping shall be "free from air leaks" and then furnishing an air pump costing a very appreciable fraction of the total plant cost to remove air specified not to be present.

4 The author believes and assumes that the amounts of air passing through different condensers may be best measured and compared on the basis of the relation of the volume of this air to the volume of the steam being condensed, both being at the pressure and temperature existing in the particular exhaust pipe. The most convenient unit of volume is the volume of the water of condensation coming from the steam. The ratio of the volume of air passing through the air pump to the volume of water of condensation is then used to measure the air.

5 The most reliable index of the proportion of air to exhaust steam customary in existing plants is to be found in the ratings of air pump capacity in general use.

6 Manufacturers of vertical twin air pumps and surface condensers usually guarantee them for 26 in. vacuum (30 in. barometer) and 110 deg. fahr. hot well temperature, with 70 deg. injection and 110 deg. discharge temperature, under which conditions it is customary to furnish an air pump of a displacement of about thirteen times the volume of the water condensed.

7 Presuming that the friction of the vapors in passing through the condenser is negligible and that the volumetric efficiency of this type of air pump is the same for the air as for the water, this rating presumes that for every unit volume of water of condensation there will be present in the air pump suction pipe 12 volumes of air, saturated at 26 in. and 110 deg., at which temperature the pressure of the steam alone is 2.58 in. abs.

8 The 12 volumes of saturated air in the air pump suction pipe is made up (Dalton's Law[1]) of

12 volumes of steam at 2.58 in. abs.
12 " " air " 1.42 " "
Total pressure, 4.00 in. abs.

[1] Dalton's Law as it relates to steam in condensers has been explained by the author in a paper delivered before the Engineers' Club of Philadelphia, thus:

Exhaust steam as it exists in practice in condensers and their piping does not conform to the steam tables because of the admixture with it of certain amounts

9 Reduced to the condition in the exhaust pipe that its volume may be comparable to the volume of the exhaust steam, this air alone becomes (according to the well-known laws of the relation of temperature, pressure and volume of gases)

$$12 \times \frac{1.42}{4} \times \frac{459.5 + 125}{459.5 + 110} = 4.37 \text{ volumes}$$

10 The unit volume of water passing through the air pump with this air was before condensation 11 000 times its volume. The proportion of air to 10,000 volumes of exhaust steam is therefore

$$\frac{4.37 \times 10\,000}{11\,000} = 4.0 \text{ volumes.}$$

11 This amount, 4.0 volumes of air per 10 000 volumes of steam, represents the upper limit of the proportion of air to exhaust steam anticipated by American practice in air pump guarantees; for the class of steam plant usually supplied with vertical twin air pumps, as indicated by the success of large numbers of these pumps in achieving their rated results.

12 Horizontal air pumps for 26 in. vacuum and 110 deg. hot well temperature are rated by most manufacturers as having a displacement of about twenty times the volume of the water of condensation. This rating presumes the presence of air in the proportion of 6.3 volumes to 10 000 volumes of exhaust steam.

13 Air pumps for jet condensers for 70 deg. injection and 26 in. vacuum, on the presumption that the discharge temperature will be 110 deg., are usually rated at a displacement of 52 times the volume

of air. The temperatures and pressures of this mixture of air and steam follow Dalton's law. Under this law the total pressure at any point is the sum of the individual pressures of the air and of the steam in the mixture at that point, whereas the temperature is that due to the steam at its individual pressure as if alone. In most condenser problems making use of this law the temperature and the sum of the individual pressures are given, the latter being the absolute pressure in the condenser. The individual pressure of the steam will be that due to the temperature and can be taken from the steam tables. The individual pressure of the air must then be the difference between this individual steam pressure and the total pressure. Having obtained these individual pressures, and knowing, therefore, that the relative volumes of the air and steam, if separated, must remain in the same proportion as their individual pressures, it is possible to calculate the exact amount of air present and to trace this amount through the condensing process.

of the water of condensation. On these presumptions, this displacement will be made up of

	Volumes
Condensed steam	1.0
Air entering with steam through boiler	0.3
Condensing water	26.0
Air entering with condensing water	10.5
Air entering by leakage	14.2
Total	52.0

14 Figuring as above, 14.2 volumes of air in the air pump suction at 4 in. absolute and 110 deg. were before condensation 4.7 volumes per 10 000 volumes of exhaust steam, or to refer to the basis used before for the surface condenser, the air entering by leakage and in the boiler feed total 14.5 volumes and correspond to 4.8 volumes per 10 000 volumes of exhaust steam.

15 Here, then, are three different amounts, 4.0, 6.3, and 4.8 volumes air per 10 000 volumes of exhaust steam which the custom of air pump guarantees establishes as the limiting proportions of air to exhaust steam in usual practice in steam engine plants. The first of these values seems most reliable because of the high volumetric efficiency of the vertical twin air pump, but as this type of pump is most often used in steam plants, which, from their nature, are likely to have less leakage than the average plant, it is probable that 4.0 volumes is a little below the average. Neither of the other two values is likely to be as reliable as the first from the nature of the assumptions necessary in their deduction. It is therefore safe to say that a provision to handle about 4.5 volumes of air per 10 000 volumes of exhaust steam at 26 in. is ample in steam engine practice, and that more air than this indicates excessive leakage, this, however, depending somewhat on the size and type of plant.

16 Of the air that must be removed from the surface condenser, part enters with the steam through the boiler from the feed water, the balance through leaks. If it be presumed that, as an outside figure, the feed water contains 1/20 of its volume of air at atmospheric conditions and is at 70 deg. fahr., its relative volume, when it reaches the exhaust pipe entering the condenser, will be:

$$\frac{1}{20} \times \frac{459.5 + 125}{459.5 + 70} \times \frac{30}{4} \times \frac{10\,000}{11\,000} = 0.38$$

volumes per 10 000 volumes of exhaust steam; or if the feed be heated to 210 deg. before being pumped into the boiler:

$$\frac{1}{20} \times \frac{459.5 + 125}{459.5 + 210} \times \frac{30}{4} \times \frac{10\,000}{11\,000} = 0.33$$

volumes per 10 000 volumes exhaust.

17 This shows that of the air pump capacity presumed necessary by manufacturers, about 7 to 9 per cent is required to handle the air coming into the condenser with the feed water and that the balance is required to remove the air entering by leakage and is largely an unnecessary expenditure. Certainly, then, the reponsibility for limiting the amount of air is with the prime mover and its piping, and it is only reasonable to expect those controlling these features of the plant to indicate the amount of air the air pump must handle and not to compel the condenser manufacturer to guess at it.

18 There seems to be no other means of measuring the air coming to any condenser than by the displacement of its air pump. The proportion of air mixed with the exhaust steam is so small that the temperature drop due to its presence could not be used. Thus, four volumes of air per 10 000 volumes of exhaust steam would cause a lowering of the temperature below that due to the pressure, of 0.014 deg. fahr. at 28 in. vacuum and 0.015 deg. at 26 in. vacuum.

19 Charts have been prepared to simplify the calculations necessary to determine the proportions of air and exhaust steam passing into the condenser, after the ratio of volume of water of condensation to volume of air passing through the air pump, and the temperature of this air, have been determined. The curves of the charts, Fig. 1 and 2, show the relations of these quantities. There are three sets of these curves in Fig. 1: for 4 in. abs. 2 in. abs. and 1 in. abs., respectively. Fig. 2 explains itself.

20 In Fig. 1, abscissæ are volumes of air added to 10 000 volumes of steam. Ordinates are ratios of the volumes of this air saturated at the temperatures marked on each curve to the volume of the water of condensation. Thus, the curve marked 26 in. and 110 deg. fahr. shows that an air pump displacement ratio of 12 volumes of air to 1 of water would, at this temperature and pressure, correspond to a mixture of 4.0 volumes of air and 10 000 volumes of steam at this same pressure, before condensation agreeing with previous calculation.

21 These curves are purely theoretical, and can be used for any type of condenser to determine the ratio after condensation of the volume of air and water at the temperatures corresponding to certain proportions of air mixed with the exhaust steam passing to the

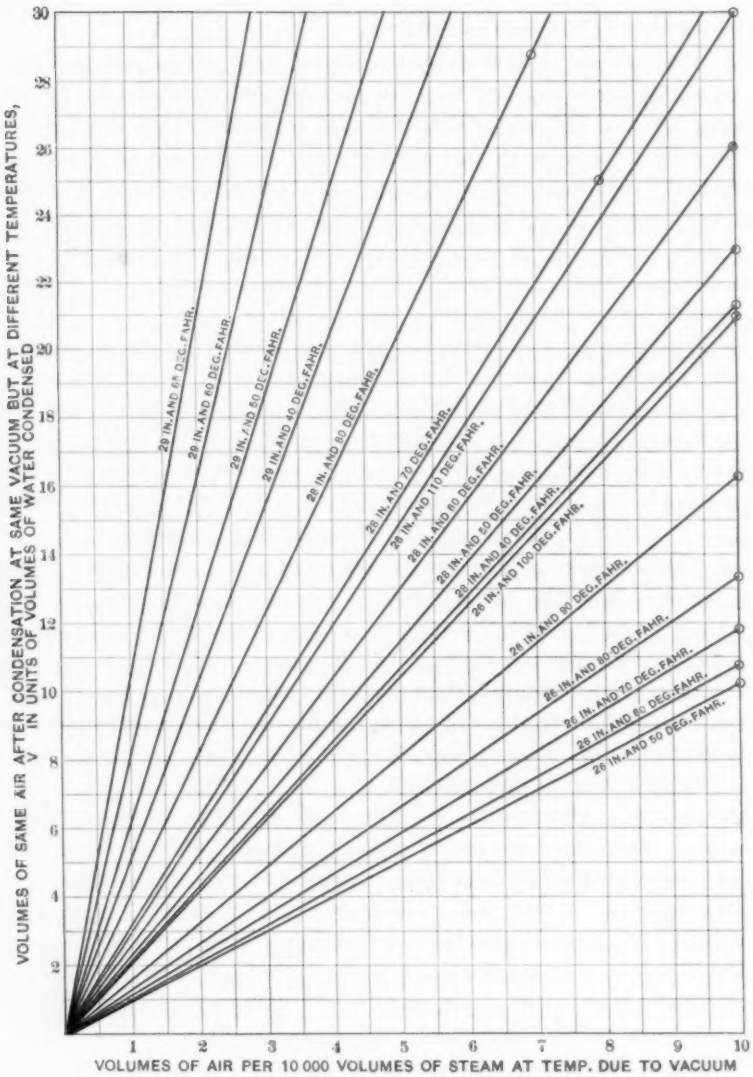
VOLUMES OF SAME AIR AFTER CONDENSATION AT SAME VACUUM BUT AT DIFFERENT TEMPERATURES, V IN UNITS OF VOLUMES OF WATER CONDENSED
VOLUMES OF AIR PER 10 000 VOLUMES OF STEAM AT TEMP. DUE TO VACUUM
29 IN. AND 60 DEG. FAHR.
29 IN. AND 50 DEG. FAHR.
29 IN. AND 40 DEG. FAHR.
28 IN. AND 80 DEG. FAHR.
28 IN. AND 70 DEG. FAHR.
28 IN. AND 110 DEG. FAHR.
28 IN. AND 60 DEG. FAHR.
28 IN. AND 50 DEG. FAHR.
28 IN. AND 40 DEG. FAHR.
28 IN. AND 100 DEG. FAHR.
26 IN. AND 90 DEG. FAHR.
26 IN. AND 80 DEG. FAHR.
26 IN. AND 70 DEG. FAHR.
26 IN. AND 60 DEG. FAHR.
26 IN. AND 50 DEG. FAHR.

FIG 1 CURVES BASED ON 30-IN. BAROMETER.

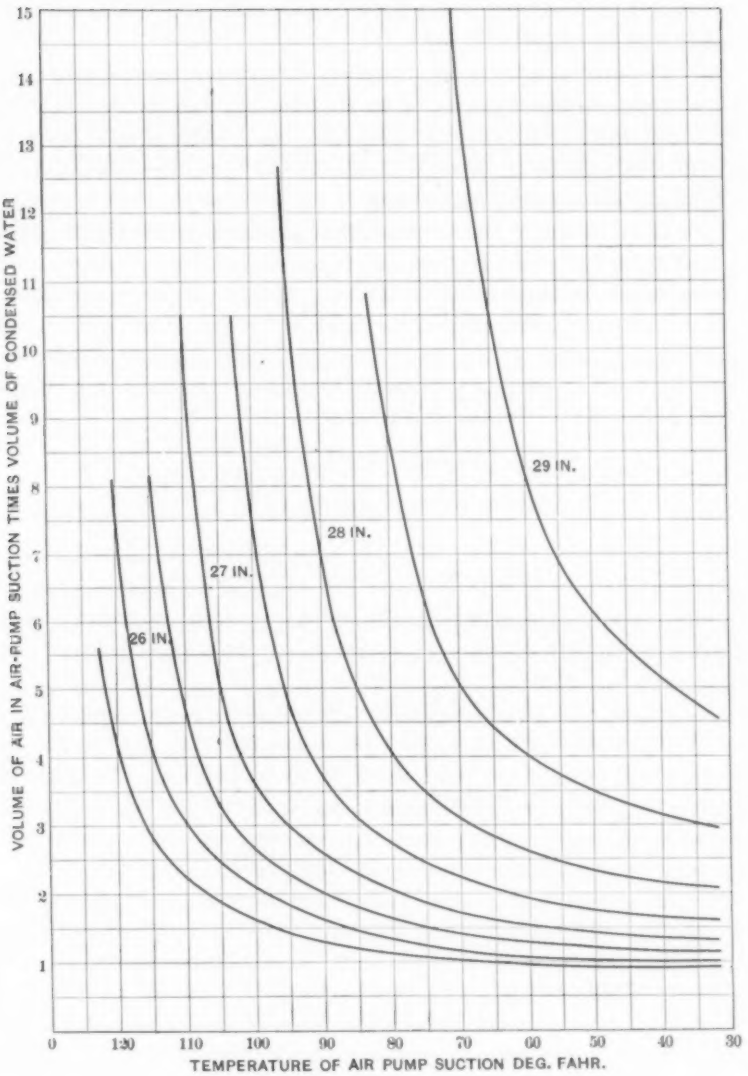

FIG. 2 RESULTING VOLUME IN AIR PUMP SUCTION DUE TO PRESSURE OF 1/10 000 PARTS BY VOLUME OF AIR IN EXHAUST STEAM

condenser and can therefore be used for selecting both dry air pump sizes and wet air pump sizes where hot well temperatures are to be guaranteed and where the proportion of air to exhaust steam is either specified or assumed.

22 The curves also show the great influence of air pump suction temperature on the capacity of an air pump to handle air. Thus an air pump with 4 in. absolute pressure can handle about twice the amount of air at 90 deg. it could handle at 110 deg. and at 40 deg. about three times its capacity at 100 deg.

23 This feature of the curves also shows quantitatively the benefit gained in reduction of volume of air by the "dry" system, using a rotative dry vacuum pump. Without sacrifice of hot well temperature, this system removes the air near or at the temperature of the injection. If used on the presumed conditions of the vertical twin pump first mentioned, 12 volumes of air at 4 in. absolute and 110 deg. would be cooled to 70 deg. and become

$$12 \times \frac{459.5 + 70}{459.5 + 110} \times \frac{1.42}{3.27} = 4.85 \text{ volumes.}$$

24 Referring to the curves it is seen that 12 volumes air and 1 volume water at 4 in. absolute and 110 deg. and 4.85 volumes air and 1 volume water at 4 in. absolute and 70 deg. were each 4.0 volumes of air and 10 000 volumes of steam (both at 26 in. and 125 deg.) before condensation.

25 The curves also show, although not accurately, the fallacy of the short rule so often used which presumes that halving the absolute pressure will double the volume of air to be handled. As a matter of fact, the volume will be increased much more than twice if there is no accompanying temperature change and at least twice unless there is a very considerable accompanying temperature reduction.

26 As an example: suppose a certain volume of air saturated at 70 deg. fahr. (0.73 in. abs.) and 4 in. abs., a usual condition in the suction pipe of a rotative dry vacuum pump when maintaining this vacuum. This air has a pressure of itself of 3.27 in. absolute. If this volume be expanded to half the pressure and the air be still kept saturated at 70 deg., the air pressure itself will be 2 in. $-$ 0.73 in. $=$ 1.27 in. and its new

volume will be $\frac{4 - 0.73}{2 - 0.73} = \frac{3.27}{1.27}$ or 2.57 times the original volume.

The actual conditions may be represented thus:

$$\left.\begin{matrix}\text{One vol. saturated air at}\\ \text{70 deg. and 4 in. abs.}\end{matrix}\right\} = \left\{\begin{matrix}\text{One vol. air at 70 deg. and 3.27 in. abs.}\\ \text{“ “ steam at 70 deg. and 0.73 in. abs.}\end{matrix}\right.$$

and becomes at 70 deg. and 2 in. abs.

$$\left.\begin{matrix}\text{2.57 vols. saturated air}\\ \text{at 70 deg. and 2 in.}\end{matrix}\right\} = \left\{\begin{matrix}\text{2.57 vols. air at 70 deg. and 1.27 in. abs.}\\ \text{2.57 “ steam at 70 deg. and 0.73 in. abs.}\end{matrix}\right.$$

If, however, in halving the pressure it is also cooled to 50 deg. fahr. (0.36 in. abs.) the new volume will be

$$1 \times \frac{459.5 + 50}{459.5 + 70} \times \frac{4 - 0.73}{2 - 0.36} = 1.92 \text{ times original volume.}$$

27 Similarly, a certain amount of air saturated at 70 deg. (0.73 in. absolute) and 28 in. becomes at 70 deg. and 29 in.

$$\frac{2 - 0.73}{1 - 0.73} = 4.7 \text{ times original volume}$$

or at 50 deg. (0.36 in. absolute) becomes

$$1 \times \frac{459.5 + 50}{459.5 + 70} \times \frac{2 - 0.73}{1 - 0.36} = 1.91 \text{ times original volume.}$$

28 All of these results are shown with fair accuracy (within 5 per cent) on the curves, although the curves in the set for each particular vacuum were intended to be referred only to other curves in the same set and not to curves for any other vacuum.

TABLE 1

RESULTS OF FOUR TESTS ON LARGE SURFACE CONDENSER

Test number	1	2	3	4
Ratio steam being condensed to guaranteed capacity of condenser for 70 deg. water and 28 in. vacuum, per cent	74	67	38	27.5
Vacuum in exhaust, 30 in. barometer, inches	28.03	28.18	28.28	27.34
Corresponding temperature, degrees fahr	101.0	97.8	95.9	109.4
Volumes exhaust steam times volume water of condensation	21 200	23 100	24 600	16 000
Steam condensed per square foot, pounds	5.62	5.1	2.85	2.07
Vacuum pump suction temperature, degrees fahr	56.7	58	58	56.2
Equivalent steam pressure, inches, abs	0.46	0.48	0.48	0.45
Air by volume in vacuum pump suction, per cent	76.5	73.7	72.2	83.4
Vacuum pump displacement times volume water of condensation	52.6	58.0	105.0	143.5
The same with 90 per cent volumetric efficiency assumed	47.3	52.2	94.5	129.1
Volume air reduced to temperature and pressure in exhaust pipe times volume water of condensation	39.6	40.7	73.3	118.0
Volumes air in exhaust steam per 10 000 volumes exhaust steam	18.7	17.6	29.8	73.7

29 If then, it be decided say, that 4.5 volumes of air per 10 000 volumes of exhaust steam shall be the permissible amount of air mixed with the exhaust steam in surface or jet condensers, and the purchaser's specifications be so drawn, the curves will show the volume of this air and consequently the effective vacuum pump capacity required for it for each vacuum and each air pump suction temperature. In the case of the jet condenser due allowance must be made for the air carried in by the injection water, an amount that can be predicted with a fair degree of accuracy provided, of course, the water be taken from a quiet pool.

30 As an example of conditions often found, the results of four carefully conducted tests of a very large surface condenser on a steam turbine are shown in Table 1. Tests No. 1 and 2 were made one a little above and one a little below nominal rating of the turbine and show from Table 1 that the air leakage in the turbine, piping and condenser based on ratio to volume of exhaust steam was about four times the largest amount customary in steam engine practice. Tests 3 and 4 not only show enormous leakage but also that the total amount of air increased as the load on the turbine decreased; a usual condition in steam turbines.

TABLE 2

RESULTS SHOWING EFFECTS OF AIR MIXED WITH STEAM

Test	Nest of tubes	Steam temperatures			Water temperatures			Difference temperatures inside and outside of tubes (?)	Steam condensed per sq. ft. per hr.	B.t.u. per hour per sq. ft.	B.t.u. per hr. per sq. ft. per deg. difference (?)	Air in steam by vol. per cent. (?)
		Entering (?)	Leaving (?)	Average (?)	Entering	Leaving	Average					
1	top	101.0	91.1	96.0	56.	66.	61.0	35.0	12.03	13020	372	6.
	middle	91.1	63.6	77.3	53.	56.	54.5	22.8	3.60	3888	171	51.
	bottom	63.6	55.3	59.4	52.	53.	52.5	6.9	1.20	1296	189	75.
2	top	97.8	91.7	94.8	56.	66.	61.0	33.8	10.89	11760	348	14.8
	middle	91.7	62.0	76.8	53.	56.	54.5	22.3	3.24	3498	156	47.
	bottom	62.0	56.0	59.0	52.	53.	52.5	6.5	1.08	1164	180	73.
3	top	96.0	89.3	92.6	54.	60.	57.0	35.6	6.12	6609	186	14.
	middle	89.3	59.4	74.3	53.	54.	53.5	20.8	1.02	1101	54	47.
	bottom	59.4	55.6	57.5	51.6	53.	52.3	5.2	1.44	1554	30	72.
4	top	109.4	100.0	104.7	54.	57.5	55.7	49.0	2.64	2851	58	16.
	middle	100.0	62.0	81.0	54.	54.	54.0	27.0				38.
	bottom	62.0	54.4	58.2	52.	54.	53.0	5.2	1.50	1620	31	82.

31 It is interesting to note the effect of the large proportion of air mixed with the steam, particularly in the bottom of the condenser, on the heat transferring capacity of the surface, as shown in Table 2. Certain of the steam temperature readings of the test were liable to error through the impossibility of knowing surely that the thermometers were not influenced by water dripping on them from the colder tubes so all of these and the values derived from them are marked (?). However, as these readings are the average of readings taken in two different parts of the condenser in each case they cannot be far wrong.

32 It is very evident from these tests that the middle and bottom nests of tubes are doing practically no work and that the reason for this is the large proportion of air in the steam surrounding them as is shown approximately by the last column of Table 2. The heating of the circulating water being largely prevented in all but the top nest of tubes, the efficiency of the circulating system is very low even at the larger loads; 14 out of a possible 46 deg. in one case and 14 out of a possible 42 deg. in another.

33 This analysis of the results of these tests reveals some features in the design of this condenser which might have been improved upon, but comment on these is irrelevant to the subject under discussion. It is, however, of interest to consider what must be done to improve the vacuum in this condenser. From the fact that the air pump suction temperature in these four tests was within 4.7, 6, 6.4, and 4.2 deg., respectively, of the injection temperature, it is inferred that the condenser is doing fairly well as an instrument for cooling, especially in view of the large proportion of air present. The fault can then be corrected only by decreasing the amount of air in the condenser either by taking care of the air leaks or by increasing the speed or size of the air pump.

34 To reduce the air in the condenser to the amount deduced for steam engine practice, the equivalent of 4.5 volumes in the exhaust pipe to 10 000 volumes of exhaust steam, would require that the air leaks shown in each of the four tests be reduced to 24.0, 25.5, 15.1 and 6.1 per cent, respectively, of their present value, or that the speed or capacity of the air pump be increased about four times at full load on the turbine, about 6.5 times at half load and about 16 times at three-eighths load. The full benefit that would result from this change is hard to calculate, as it affects so many different features of the condenser. The first effect would be to reduce to one-quarter the proportion of air in the air pump suction pipe. As there is an ample amount of cooling effect, this change would not materially affect the

air pump suction temperature. Taking Test 1 as an example, where the pressure of the steam alone in the air pump suction pipe (Table 1, line 8) was 0.46 in. and the air pressure therefore 1.97 − 0.46 = 1.51 in.; a reduction of the latter to one-quarter would result in a pressure of 0.46 + 0.38 = 0.84 in. abs., plus an allowance for the falling off in the efficiency of the vacuum pump at the higher vacuum. Practically, at least, 0.9 in. abs. might have been expected.

35 The curves also show that with 70 deg. injection temperature, presuming that the air pump suction temperature could not be more than 75 deg., the vacuum with same load and same air leakage as Test 1 would be 2.5 in. and with the leakage usual with steam engines would be equal to 1.3 in.

36 This excessive leakage was, therefore, causing a winter vacuum of 28.03 that ought to have been at least 29.1 in. and was likely to cause a summer vacuum of only 27.5 in. where it should have been at least 28.7 in. The winter loss of fuel, due to the excessive leakage of this unit, averaged probably half a ton per hour. In spite of this enormous loss and in spite of the fact that it was known that the vacuum was not what it should have been, no attempt was made to analyze the results obtained on a scientific basis to locate the cause of the trouble; in fact, the engineers concluded that the air pump was too large, whereas it was entirely too small for the air leaks present.

37 It is to be regretted that there is not more information available on which exact estimates of air leakage can be made. There are turbine plants comparable in size with the plant cited above, in which the air leakage is less than we have assumed as the maximum allowable amount in steam engine practice.

38 It must also be evident that comparisons of results obtained in different plants and from different types of condensers cannot possibly be trustworthy unless the proportion of air for each case has been determined and due allowance made therefor. The amount of air present exerts a great influence on (a) the relation between temperature and vacuum in the condenser; (b) on the air removing capacity of the air pump; and (c) on the heat transferring capacity of the surface or spray. The plant so fortunate as to have the smallest air leakage might have an advantage sufficient to wipe out entirely the benefits that might be gained by any refinements in the design of a condenser under comparison. Thus, a comparison between the condenser referred to in Tables 1 and 2, which was provided with a cooler, and a unit which had its cooler removed, shows results apparently favoring the latter. The methods of measuring and comparing

air leakages suggested in this paper would not only show this to be an erroneous conclusion and that air cooling was of great benefit to the unit, but it would also show the amount to be gained by such cooling.

39 The suggested measurement of the air coming to condensers necessitates the following readings:

1. Pressure in air pump suction.
2. Temperature of air pump suction.
3. Quantity of steam being condensed.
4. Effective vacuum pump displacement.

40 For ordinary work and with properly built condensers, the vacuum in the condenser could be taken for the first reading, but for exact work the pressure and temperature should both be taken at the same point in the suction pipe. The third quantity is generally well known. The fourth quantity requires readings of the speed of the vacuum pump and an estimate of its volumetric efficiency from its indicator card.

41 For barometric condensers and jet condensers with air pumps, certain allowances have to be made, requiring for their determination some previous practice with condensers of other types.

42 As the data necessary for the estimation of air in condensers is so easily obtained, it is hoped that this paper will eventually result in the application of the same scientific methods to air leakage in condensers that are now applied to all the other features of the power house. A full appreciation of the effect of air in condensers on coal consumption and an exact knowledge of the amount and probable source of this air should result in generally higher vacuums and an increase both in the efficiency and capacity of the plant. The methods suggested in this paper can be used in the analysis of existing condenser plants to see how their results can be improved, assisting in determining whether the cooling features or the air removing features are limiting the vacuum and if the latter, determining just what improvements could be made and how much.

43 It is hoped that engineers in testing condensers will make it a point to estimate the air present and publish their results to the end that more may be known of the possibilities of reducing air leakage, and the maximum amount allowable in good practice established, that eventually air incondensers may cease to be the subject of guesswork.

ECONOMY TESTS OF HIGH SPEED ENGINES

TESTS TO DETERMINE ECONOMY AND EFFICIENCY OF NON-CONDENSING RECIPROCATING STEAM ENGINES IN ACTUAL OPERATION.

By F. W. Dean, Boston, and A. C. Wood, Philadelphia

Members of the Society

While there has already been published a large number of data on the economic performance of various high speed non-condensing engines with or without electric generators attached, additional data are here given of several tests that have been made by the authors during the year 1907.

2 Several months ago it became necessary to make tests of several different high-speed engines, direct connected to electric generators, for the purpose of determining the quantity of steam used per indicated horse power per hour, per kilowatt hour, and to determine some other characteristics. The idea was to take the engines as they were found in order to ascertain their economy after having been run for some time, and to state as nearly as could be determined the number of hours that they had been in actual running service. It was not desired to do anything to improve the economy, or to remove any defects, except to equalize the work done at both ends of the cylinders, if they should prove to be unequal, by adjusting the lengths of the valve stems. The diameters of the cylinders and piston rods, and the lengths of the strokes were measured.

3 The engines tested were of the types and sizes stated below, those numbered 1, 2, 3, 4, and 5, having been tested by Mr. Dean, and those denoted by A, B, and C, by Mr. Wood.

To be presented at the Detroit Meeting (June 1908) of The American Society of Mechanical Engineers.

The professional papers contained in Proceedings are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present. They are issued to themembers in confidence, and with the understanding that they are not to be published even in abstract, until after they have been presented at a meeting. All papers are subject to revision.

The Society as a body is not responsible for the statements of facts or opinions advanced in papers or discussions. C55.

1 15 in. by 14 in. by 240 r.p.m. horizontal single flat valve engine with a 100 kw. d.c. generator on the shaft.

2 16 in. by 15 in. by 240 r.p.m. vertical single flat valve engine with two 50 kw. d.c. generators on the shaft.

3 14 in. by 12 in. by 300 r.p.m. horizontal single flat valve engine with two 40 kw. d.c. generators on the shaft.

4 16 in. by 14 in. by 270 r.p.m. horizontal engine with four flat valves, and having a 125 kw. a.c. generator on the shaft.

5 12 in. and 19 in. by 14 in. by 230 r.p.m. vertical cross compound condensing piston valve engine with a 100 kw. d.c. generator on the shaft.

A 18 in. by 18 in. by 220 r.p.m. horizontal single piston valve engine with a 150 kw. d.c. generator on the shaft.

B 15 in. by 16 in. by 250 r.p.m. horizontal single piston valve engine with a 100 kw. d.c. generator on the shaft.

C 12 in. by 18 in. by 190 r.p.m. horizontal engine with two flat inlet valves and two Corliss exhaust valves, and having a 75 kw. d.c. generator on the shaft.

4 These units are of types and makes frequently used in isolated plants in office buildings and elsewhere, and the results of the tests should give a very fair idea of the economy to be expected from such engines after they have been in use for some time.

5 In conducting the tests every care was taken to obtain accurate results. The engines were supplied by steam from isolated boilers, except where the steam used was condensed. In the tests made by Mr. Dean the water was weighed on platform scales, and in those made by Mr. Wood it was measured in calibrated tanks. Water levels in boilers were maintained as near a constant level as practicable. After the tests made by Mr. Wood were finished, leakage tests were made of the boilers and steam piping, but this was not done by Mr. Dean.

6 In order to avoid as far as possible inaccuracies due to differences in apparent quantity of water in boilers, due to any cause, the weights of water were plotted to see whether the resultant points were on, or nearly so, a straight line. In every case from this criterion the results were satisfactory.

7 The quality of the steam was determined in every case, but no correction for this was made by Mr. Dean because in his opinion the results would scarcely have been more accurate thereby, but Mr. Wood applied corrections for entrainment.

8 Indicator springs were tested and corrections were made when necessary.

9 Electrical instruments used by Mr. Wood were compared with the sub-standards of the Philadelphia Electric Company and the Keystone Electrical Instrument Company, and the readings corrected in accordance with the results of these calibrations. In the case of Mr. Dean's tests the electrical instruments were calibrated in some cases by comparison with standard instruments loaned by the Edison Electric Illuminating Company of Boston, and in the other cases the errors of the regular instruments were determined by Professor Laws of the Massachusetts Institute of Technology. The tests made by Mr. Dean were carried out and worked up by Mr. Charles H. Chase, Assistant Professor of Steam Engineering at Tufts College, under Mr. Dean's general direction.

10 Indicator diagrams and speeds were taken at frequent intervals.

11 The loads were maintained by water rheostats except in the case of Engine No. 1 where a steady lighting load was carried.

TESTS OF ENGINE NO. 1

12 This is a simple horizontal non-condensing balanced slide-valve engine, running at 240 r.p.m., and having a cylinder 15 in. in diameter by 14 in. stroke. It is direct connected to a 100 kw. Fort Wayne d.c. electric generator, working at approximately 220 volts. The engine is used for power and lighting and the load was sufficiently steady for test purposes.

13 As far as economy is concerned the most interesting feature is the slide valve. This is a long rectangular valve, the center being cut out, and ports cast through each end of the valve. The valve runs on edge and between the valve seat proper and a heavy balance plate held in place by steam pressure and by a heavy flat spring. It is prevented from pinching the valve by strips of cast iron slightly thicker and longer than the valve, one being above and the other below the valve. In the balance plate there are depressions directly opposite the steam and exhaust ports, and of the same shapes and dimensions of those ports. Thus the valve is subjected to the same pressure conditions on one side as on the other, and is therefore perfectly balanced. It is also double ported on both steam and exhaust.

14 It will be seen that in order to render this valve tight the workmanship on the valve seat, valve, balance plate and distance strips,

must be of exquisite quality. If the valve should wear slightly it would leak and grow worse with further wear, for there is no means of this wear being taken up automatically as it proceeds. By scraping the distance strips the balance plate can be brought close to the valve again and the original condition of tightness restored.

15 As valves of this kind are perfectly balanced it is not expected that there will be much, if any, wear, but to what extent this is true I am unable to say beyond what may be indicated by the results of these tests.

16 Readers will recognize in this description the valve described by Prof. John E. Sweet in a paper published in the Transactions of this Society, vol. 1, entitled "Friction as a Factor in Motive Power Expenses."

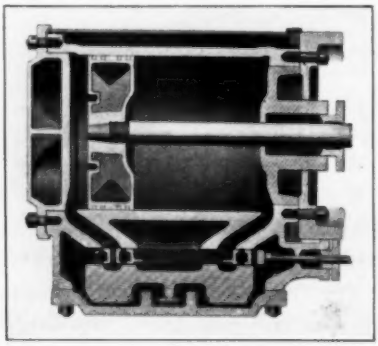

FIG. 1 SHOWING VALVE CHEST OF ENGINE NO. 1

17 The governor is of the flywheel type. The eccentric is moved in one direction by a weight subjected to centrifugal force, and in the other by a flat leaf spring connected to the weight by a flat steel band.

18 The feed water was weighed in a barrel resting on platform scales and emptied into a lower barrel, from which a specially installed feed pump drew it and forced it into one vertical fire tube boiler. The feed pipe was disconnected from other boilers. The steam pipe from the boiler was equipped with two stop valves, and a small bleeding pipe to the atmosphere was inserted between them. On shutting both valves and opening the bleeding pipe no steam escaped, thus, fortunately, showing both valves to be tight. A special pipe was run from a flanged nozzle on the boiler steam pipe to the engine, and therefrom the regular steam pipe was disconnected. All of the usual precautions to prevent inaccuracies were taken.

19 As the boiler was of the vertical fire tube type the steam was somewhat superheated at the engine.

20 It was considered of importance that the indicator diagrams should be worked up as having no back pressure. As each diagram had some back pressure an average diagram from each test (determined by selecting a diagram having a mean effective pressure equal to the average) was taken and an exhaust line of no back pressure was plotted upon it. In order to know just how to plot this line, and the release and compression curves, a number of diagrams

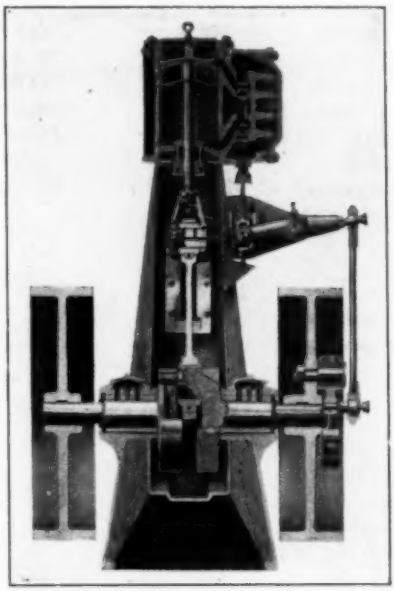

FIG. 2 SHOWING VALVE CHEST OF ENGINE NO. 2

with different back pressures were taken from an engine (although of another make) having a stop valve in the exhaust pipe. If the exhaust line was not quite correct it could not have been sufficiently erroneous to vitiate the results to any important extent.

TESTS OF ENGINE NO. 2

21 This is a vertical engine having a valve and governor which are of the types described for Engine No. 1, and to which that description applies.

RESULTS OF TESTS OF ENGINE NO. 1

1.	Test No.	4	5	6
2.	Date 1907	Aug. 7	Aug. 8	Aug. 8
3.	Previous length of service		1 5216 hours	
4.	Size of cylinder		15 in. x 14 in.	
5.	Diameter piston rod		2⅞ in.	
6.	Generator		Ft. Wayne d.c. 6-pole	
7.	" rating		100 kw.—220 volts — 400 amp.	
8.	Duration of tests	2 hr.	2½ h.	3 h.
9.	Approximate load	½	½	¾
10.	Superheat of steam	7 deg. fahr.	14 deg. fahr.	12 deg fahr.
11.	Average steam pressure	83.0 lb.	83 lb.	81.5 lb.
12.	" revs. per min.	242.9	240.8	240.3
13.	" temp. of steam	333 deg.	339 deg.	337 deg.
14.	" " " room	98 deg.	101 deg.	102 deg.
15.	" " " atmos.	92 deg.	100 deg.	99 deg.
16.	Average barometer	14.69 in.	14.69 in.	14.69 in.
17.	Indicator spring, lb.	60	60	60
18.	Indicated horse power	92.60	89.75	106.00
19.	" friction h.p.[1]			4.22
20.	" " " per cent			3.98
21.	Indicated h.p. to atmos.	107.5	105.3	123.3
22.	Average back presssure	4.3 lb.	5.5 lb.	4.6 lb.
23.	" cut off, per cent	30.7	31.0	38.5
24.	" amperes	250.6	246.8	295.7
25.	" volts	222.5	222.2	221.2
26.	" kw.	55.8	54.8	65.4
27.	" " to atmos.	66.4	65.0	76.4
28.	Efficiency e.h.p. to i.h.p., per cent	82.3	82.3	82.7
29.	Total water consumed, lb.	8280	9771	13 384
30.	Water consumed per hr., lb.	4140	3916	4461
31.	Water per i.h.p. per hr., observed lb.	44.7	43.6	42.1
32.	Water per i.h.p. per hr., to atmos., lb.	38.5	37.2	36.2
33.	Water per kw. per hr., observed lb.	74.2	71.5	68.2
34.	Water per kw. per hr., to atmos. lb.	62.3	60.2	58.4

[1] Generator unexcited.

22 It is direct connected to two direct current electric generators, the current of which is used for motors and for lighting. The work was irregular and not satisfactory for test purposes. In consequence of this a water rheostat for furnishing the load was made, and the tests were carried on when the engine was not needed for its regular service.

23 The water for making steam was weighed and pumped into two horizontal return tubular boilers by a pump operated by a third boiler, this boiler being separated in all respects from the other two. The quality of the steam was determined by a Peabody calorimeter.

RESULTS OF TESTS OF ENGINE NO. 2

1.	Test No.	7	8
2.	Date	1907 Aug. 17	Aug. 24
3.	Previous length of service	20 000 hours	
4.	Size of cylinder	16 in. x 15 in.	
5.	Diam. piston rod	2½ in.	
6.	Generators	Two General Electric	
7.	Generator rating	Each 50 kw.—400 amp. 125 V.	
8.	Duration of tests	3 hr.	3½ hr.
9.	Approximate load	Full	½
10.	Quality of steam	97.6	97.4
11.	Average steam pressure	75 lb.	75.6 lb.
12.	" revs. per minute	240.8	242.4
13.	" temp. of room	96 deg.	82 deg.
14.	" " " atmos.	81 deg.	66 deg.
15.	" barometer, in.	14.80	14.70
16.	Indicator spring	60 lb.	60 lb.
17.	Indicated horse power	153.1	101.3
18.	" friction h.p.[1]	12.86	
19.	" " " per cent	8.39	
20.	Indicated horse power to atmospheric line	159.5	109.5
21.	Average back pressure	1.85	1.40
22.	" cut off, per cent	46.85	29.3
23.	" kw.	91.2	55.3
24.	" " to atmospheric line	95.8	61.0
25.	Efficiency e.h.p. to i.h.p., per cent	80.0	74.2
26.	Total water consumed, lb.	17 154	14 093
27.	Water consumed per hr., lb.	5718	4027
28.	" per i.h.p. per hr. observed, lb.	37.3	39.7
29.	" " i.h.p. per hr. to atmos., lb.	35.8	36.7
30.	" " kw. per hr. observed, lb.	62.7	72.8
31.	" " kw. per hr. to atmos., lb.	59.7	66.0

[1] Generator unexcited.

TESTS OF ENGINE NO. 3

24 This is a horizontal engine direct connected to two electric generators, and is used on power and lighting. As the load was irregular it was necessary to use a water rheostat.

25 The boilers were of the horizontal return tubular type and weighed water was pumped into them.

26 This engine is equipped with a peculiar type of balanced valve. It slides between two seats, one on the top and one on the bottom of the steam chest, the ports being cast in the top and bottom of the chest and finally coming together and passing to the ends of the cylinder. The steam enters the inside of the valve and being admitted to both top and bottom ports simultaneously, the valve is,

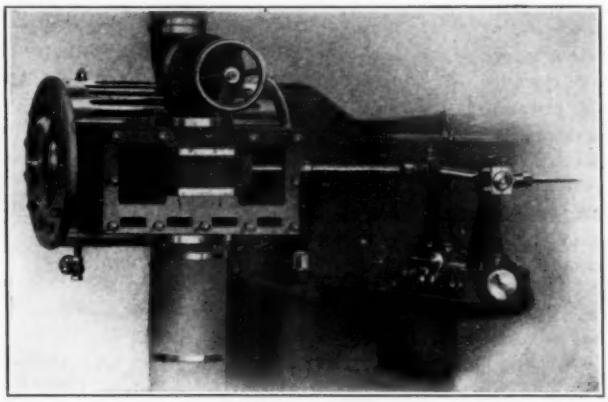

FIG. 3 SHOWING VALVE CHEST OF ENGINE NO. 3

in effect, double ported. Similarly the exhaust comes from both top and bottom and the valve is therefore double ported on the exhaust.

27 The valve is not a single piece without adjustment, but on the contrary the top and bottom of the valve are two separate pieces having circular backs, one fitting inside of the other and being packed with sprung rings. The valve is sufficiently unbalanced to keep the two parts against their respective seats with slight pressure, and thus they follow up any wear that takes place, and will, it is expected, keep tight under the circumstances of ordinary service.

The engine is provided with a Rites governor.

RESULTS OF TESTS OF ENGINE NO. 3

1.	Test No.		9	10
2.	Date	1907	Aug. 31	Sept. 3
3.	Previous length of service		28 644 hrs.	
4.	Size of cylinder		14 in. x 12 in.	
5.	Diameter of piston rod		$1\frac{3}{4}$ in.	
6.	Generators		Two General Electric	
7.	Generator rating		Each 40 kw. 354 amp. 110 V.	
8.	Duration of tests		3 hr. 2 m.	3 hr.
9.	Approximate load		Full	$\frac{1}{2}$
10.	Quality of steam		98.1	98.5
11.	Average steam pressure		90.8	91.1
12.	" revs. per minute		304.1	300.0
13.	" temp. of room		95 deg.	98 deg.
14.	" " " atmos.		70 deg.	67 deg.
15.	" barometer		14.70 in.	14.74 in.
16.	Indicator spring		60 lb.	60 lb.
17.	Indicated horse power		124.4	79.13
18.	" friction h.p. [1]		4.34	
19.	" " " per cent		3.49	
20.	" horse power to atmospheric line		146.0	93.23
21.	Average back pressure		8.20	3.85
22.	" cut off, per cent		45.3	25.1
23.	" kw. observed		69.1	44.0
24.	" " to atmospheric line		81.4	51.7
25.	Efficiency e.h.p. to i.h.p., per cent		74.3	73.9
26.	Total water consumed, lb.		14 166	8856
27.	Water consumed per hr., lb.		4670	2952
28.	" per i.h.p. per hr. observed, lb.		37.5	37.3
29.	" " i.h.p. per hr. to atmos., lb.		32.0	31.7
30.	" " kw. per hr. observed, lb.		67.6	67.1
31.	" " " " " to atmos. lb.		57.4	57.1

[1] Generator unexcited.

TESTS OF ENGINE NO. 4

28 This is a horizontal center crank engine with four slide valves. The two inlet valves are on one side of the cylinder, one valve being on each end, and the two exhaust valves are similarly situated on the other side of the cylinder. Each valve slides between its seat and a balance plate and is perfectly balanced and double ported. Compensation for wear is provided by scraping the strips that maintain the balance plate at a fixed distance from the seat. The ports are direct and the clearance evidently small.

29 The governor is of the Rites type, and acts on the inlet valves. The exhaust valves are operated by a fixed eccentric.

RESULTS OF TESTS OF ENGINE NO. 4

1.	Test No.	1	2	3
2.	Date 1907	Aug. 2	Aug. 1	Aug. 2
3.	Previous length of service		719 hours	
4.	Size of cylinder		16.09 in. x 14 in.	
5.	Diameter of piston rod		2½ in.	
6.	Generator		Allis-Chalmers-Bullock	
7.	" rating		125 kw., 3 ph., 600 V. 120 amp.	
8.	Duration of tests, hr.	3½	6	3½
9.	Approximate load	½	¾	Full
10.	Quality of steam—superheated	18 deg. fahr.	22 deg. fahr.	19 deg. fahr.
11.	Av. steam pressure, lb.	113.3	111.6	113.9
12.	" revs. per minute	268.9	268.3	264.0
13.	" temp. of steam	364 deg.	367 deg.	365 deg.
14.	" " " room	85 deg.	88 deg.	89 deg.
15.	" " " atmos.	80 deg.	83 deg.	85 deg.
16.	" barometer, in.	14.70	14.69	14.68
17.	Indicator spring, lb.	80	80	80
18.	Indicated horse power	99.36	138.1	184.0
19.	" friction h.p.[1]			9.70
20.	" " " per cent			5.27
21.	" horse power to atmospheric line	114.7	159.7	214.0
22.	Av. back pressure, lb.	3.5	5.1	8.3
23.	" cut-off, per cent	16.5	27.0	40.1
24.	" kw. observed	63.1	94.3	124.3
25.	" " to atmos. line	76.0	109.3	143.3
26.	Efficiency e.h.p. to i.h.p. per cent	84.7	91.0	90.0
27.	Total water consumed, lb.	15 900	35 987	27 465
28.	Water consumed per hr., lb.	4543	5998	7850
29.	" per i.h.p. " " observed, lb.	45.7	43.4	42.7
30.	Water per i.h.p. per hr. to atmos. lb.	39.6	37.5	36.7
31.	Water per kw-hr., observed lb.	72.0	63.6	63.1
32.	Water per i.h.p. per hr. to atmos. lb.	59.8	54.9	54.7

[1] Generator unexcited.

30 The engine is direct connected to a Bullock 3-phase alternating generator of 125 kw. capacity.

31 The steam was condensed in a surface condenser of large size and an abundant supply of circulating water was supplied. A cover over an opening on the condenser was removed in order to prevent a vacuum from being formed. The condenser was sufficiently high to permit the water formed by the condensation of the steam to run into either of two barrels each resting on a platform scale, where it was weighed. The condenser was tested for leaks, and found to be tight.

32 The steam from this engine was furnished by vertical fire-tube boilers and was somewhat superheated.

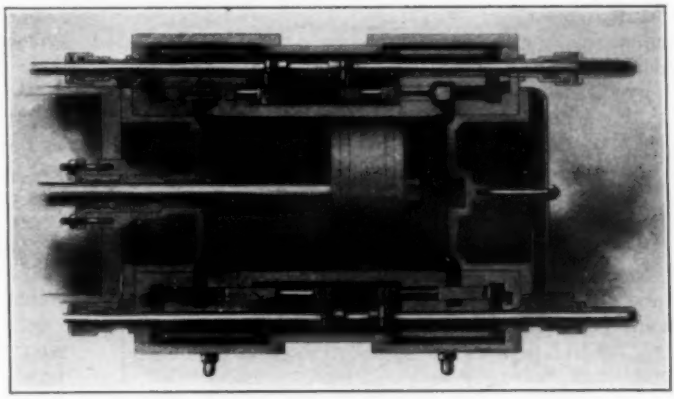

FIG. 4 SHOWING VALVE CHESTS OF ENGINE NO. 4

TESTS OF ENGINE NO. 5

33 While it was not intended to test any condensing engines it was finally decided to test one as a matter of general interest. Engine No. 5 was a vertical cross compound in rather poor condition, judging from the noise made by it. It was provided with a surface condenser which leaked somewhat, but the leakage rate was determined. While the accuracy of this test is not as great as is desirable it will, I believe, give some idea of the engine's performance. It is to be regretted that the results of the two tests are so dissimilar and I am unable to give any reason for this.

34 This engine is provided with two piston valves for each cylinder, one being the cut-off riding inside of the inlet valve, and

RESULTS OF TESTS OF ENGINE NO. 5

1.	Test No.	11	12
2.	Date	1907 Sept. 8	Sept. 8
3.	Previous length of service	15 000 hr.	
4.	Size of cylinder	$12\frac{1}{32}$ in. and $19\frac{1}{16}$ in. x 14 in.	
5.	Diameter piston rod	$2\frac{1}{32}$ in. and $2\frac{3}{8}$ in.	
6.	Generator	One General Electric	
7.	" rating	100 kw. d.c. 220–230 V.	
8.	Durations of tests, hr.	3	2
9.	Approximate loads	8/10	7/10
10.	Quality of steam	99.2	99.3
11.	Av. steam pressure, lb.	113.8	114.9
12.	" revs. per minute	229.8	231.5
13.	" temp. of room	77 deg.	81 deg.
14.	" " " atmos.	70 deg.	66 deg.
15.	" barometer	14.73 in.	14.75 in.
16.	Indicator springs	80 high	20 low
17.	Indicated horse power	141.1	123.3
18.	" friction h.p.[1]	10.2	
19.	" " " per cent	7.2	
20.	" h.p. to 26 in. vac.	158.5	133.0
21.	Av. cut-off h.p. cyl.	33	21
22.	" " l. p. "	38	25
23.	" kw. observed	83.1	70.9
24.	" " to 26 in. vac.	95.0	77.4
25.	Efficiency e.h.p. to i.h.p. per cent	78.5	76.7
26.	Total water used, lb.	10 595	4951
27.	Water per hour "	3532	2476
28.	" " i.h.p. observed, lb.	25	20.1
29.	" " " to 26 in. vac., lb.	22.3	18.6
30.	" " kw. hr. observed, lb.	42.5	34.9
31.	" " " " to 26 in. vac., lb.	37.2	32.0
32.	Dry steam per i.h.p. hr. to 26 in. vac. lb.	22.1	18.4
33.	" " " kw. " to 26 in. vac. lb.	36.8	31.8

[1] Generator unexcited.

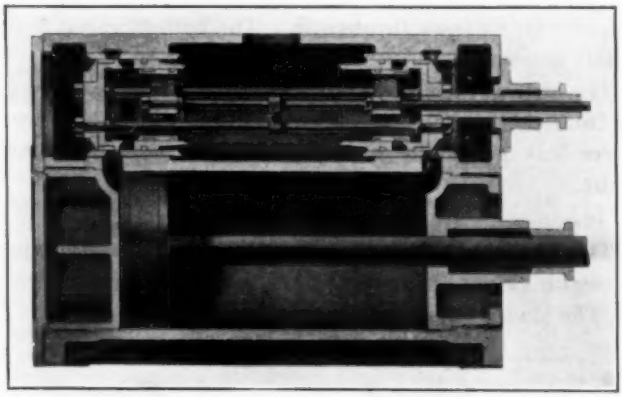

FIG. 5 SHOWING VALVE CHEST OF ENGINE NO. 5

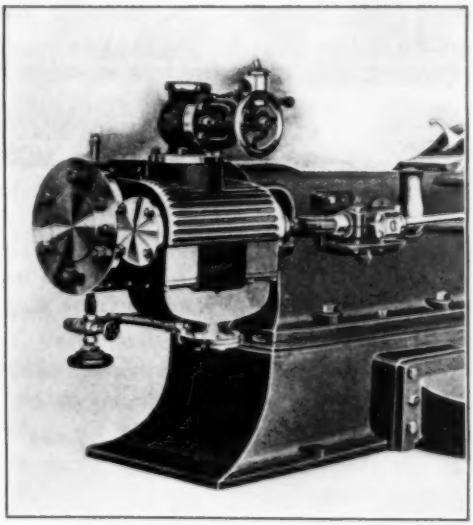

FIG. 6 SHOWING TYPE OF ENGINE A

having a motion relative to it through the intervention of a rocker mounted on another rocker, which gives motion to the inlet or main valve. The main valve has a hollow valve stem, and the stem of the cut-off valve passes through it. The cut-off valve is controlled by a shaft governor.

35 The steam consumption was determined by weighing the discharge from the condenser, and making proper allowance for the condenser leakage. This engine was direct coupled to one electric generator.

TESTS OF ENGINE A

36 This is a horizontal side crank simple non-condensing engine with a piston valve, direct coupled to a 150 kw. direct-current generator. The load was carried by a water rheostat.

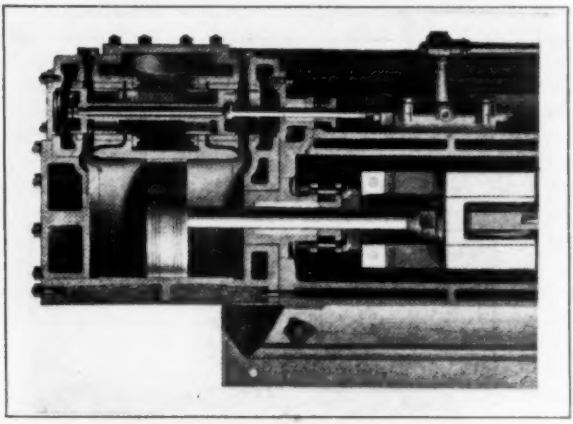

FIG. 7 SHOWING VALVE CHEST OF ENGINE B

37 The valve is an adjustable piston operating in removable bushings. The steam enters the center of the valve and exhausts at the ends. The governor is of the shaft type.

38 The engine began service September 7, 1903, and the cylinder was re-bored in 1906 and provided with a new piston. The condition of the engine was considered good, except for slight leakage of the valve. It had run about 32 000 hours, of which about 4300 hours were since re-boring the cylinder.

TESTS OF ENGINE B

39 This is a horizontal center crank engine with a piston valve. The valve has a center admission and end exhaust and is double

RESULTS OF TESTS OF ENGINE A

1.	Test No.	1	2	3
2.	Date	November 11, 1907		
3.	Previous length of service	About 32 000 hr.		
4.	Size of cylinder	$18\frac{1}{16}$ in. x 18 in.		
5.	Diameter of piston rod	3 in.		
6.	Generator	General Electric Co., d. c.		
7.	" rating	150 kw., 112 volts, 1339 amp.		
8.	Duration of tests	3 hr.	3 hr.	3 hr.
9.	Approx. load	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{1}{2}$
10.	Av. steam pressure, lb.	115.6	114	111.4
11.	" revs. per minute	221.7	221.9	222.8
12.	Indicated horse power	273.8	170.8	122.4
13.	" friction h.p.[1]	4.4		
14.	" " " per cent	1.6		
15.	Av. back pressure, lb., in exhaust pipe	0.32	0.12	0.07
16.	" amperes	1622	1020	703
17.	" volts	114.3	112.1	112.0
18.	" kilowatts	186.2	114.3	78.8
19.	Efficiency e.h.p. to i.h.p., per cent	91.16	89.70	86.28
20.	Total water consumed, lb.	24 400	17 833	14 645
21.	Water consumed per hour, lb	8133	5944	4882
22.	" " " i.h.p. per hour observed lb.	29.70	34.80	39.89
23.	" consumed per i.h.p. per hr. to atmos., lb.	29.53	34.67	39.75
24.	" consumed per kw-hr. observed, lb.	43.68	52.00	61.95
25.	" consumed per kw-hr. to atmos., lb.	43.42	51.80	61.76

[1] Generator unexcited.

ported. The steam chest, although containing a piston valve is shaped as for a flat valve and has a bare circular bonnet on the side as well as one on the end. The engine is equipped with the H. C. Nichols governor.

40 This engine was installed in April 1906, and has been in service about 5600 hours. A new valve was put into the engine a short time before the test was made, and there were thereafter slight leaks of the valve and piston.

TESTS OF ENGINE C

41 This is a horizontal side crank high speed engine having four valves. The admission valves are on the side of the cylinder and are of the perfectly balanced type, sliding between the seat and a heavy balance plate. They are in effect double ported and

RESULTS OF TESTS OF ENGINE B

1.	Test No.	1	2	3	4
2.	Date	Dec. 17, 1907			
3.	Previous length of service	5600 hours			
4.	Size of cylinder	$15\frac{1}{2}$ in. × 16 in.			
5.	Diameter of piston rod	$2\frac{3}{4}$ in.			
6.	Generator	Fort Wayne d.c.			
7.	" rating	100 kw.,	115 volts,	870 amp.	
8.	Duration of tests, hr.	3	3	3	3
9.	Approx. load	Full	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$
10.	Av. steam pressure, lb.	88.7	90.9	92.1	82.2
11.	Av. rev. per min.	244.3	246.2	248.8	247.8
12.	Indicated horse power observed, i.h.p.	137.6	102.9	69.3	36.2
13.	" friction h.p.[1]	7.2			
14.	" " h.p., per cent	5.2			
15.	Av. back pressure in exh. pipe, lb.	0.62	0.52	0.74	0.82
16.	" amperes	836	593	377	168
17.	" voltage	111.6	114.1	114.1	112.7
18.	" kilowatts	93.3	67.7	43.1	18.9
19.	Efficiency e.h.p. to i.h.p. per cent	90.9	88.2	83.3	69.8
20.	Total water consumed, lb.	14 080	11 419	8797	6118
21.	Water consumed per hr. lb.	4693	3806	2932	2039
22.	" " " i.h.p. per hr. observed, lb.	34.1	37.0	42.3	56.3
23.	Water consumed per i.h.p. per hr. to atmos. lb.	33.55	36.3	40.7	52.0
24.	Water consumed per kw-hr. observed, lb.	50.3	56.2	68.1	107.9
25.	Water consumed per kw-hr. to atmos. lb.	49.4	55.2	64.8	96.7

[1] Generator unexcited

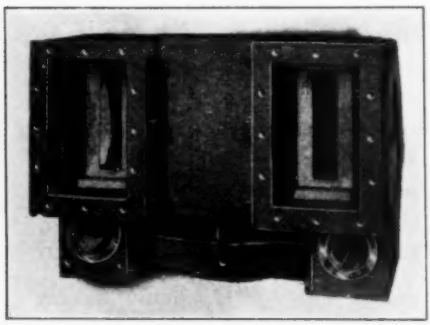

FIG. 8 VALVE SEATS, ENGINE C

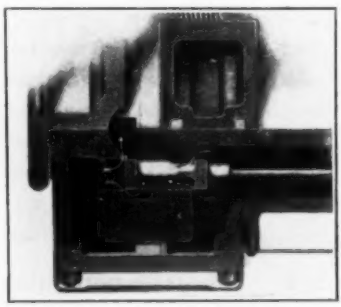

FIG. 9 ADMISSION VALVE, ENGINE C

are almost exactly as already described for the inlet valves of the four valve engine tested by Mr. Dean. As in that case there are no packing strips to prevent leakage, and tightness depends upon perfect workmanship and fitting. It is not expected that these valves will wear materially, if at all, but if they should, they, and the balance plates and distance strips can be re-fitted.

42 The exhaust valves are under the cylinder, are cylindrical, and are like many Corliss valves.

43 The governor is of the shaft type and does not differ materially from many others. The centrifugal force of the weights is balanced by a flat leaf spring

44 This engine began service on February 22, 1904, and has run about 13 000 hours. No repairs have been made and it is thought that the engine is not in the best condition.

RESULTS OF TESTS OF ENGINE C

1.	Test No.	1	2	3
2.	Date	Dec. 28, 1907		
3.	Previous length of service	10 800 hours		
4.	Size of cylinder	12 in. × 18 in.		
5.	Diameter of piston rod	2¼ in.		
6.	Generator	Quaker City d.c.		
7.	" rating	75 kw., 250 volts, 300 amp.		
8.	Duration of tests, hr.	2½	3	3½
9.	Approx. loads	50 per cent overload	Full	½
10.	Av. steam pressure, lb.	90.2	86.3	90.4
11.	" revs. per min.	186.4	188.0	189.0
12.	Indicated horse power observed, i.h.p.	111.3	74.2	43.0
13.	Av. friction horse power[1]		7.1	
14.	" " " " per cent		9.5	
15.	" back pressure in exh. pipe, lb.	0.20	0.08	0.00
16.	" amperes	308.5	198.2	105.5
17.	" voltage	228.2	227.5	226.5
18.	" kilowatts	70.40	45.15	23.89
19.	Efficiency e.h.p. to i.h.p., per cent	84.8	81.7	74.5
20.	Total water consumed, lb.	9496	8200	6626
21.	Water consumed per hr., lb.	3796	2733	1893
22.	" " " i.h.p. per hr. observed, lb.	34.10	36.80	44.02
23.	" " " i.h.p. per hr. to atmos., lb.	34.00	36.73	44.02
24.	" " " kw-hr. observed, lb.	53.92	60.60	79.30
25.	" " " kw-hr. to atmos., lb.	53.74	60.48	79.30

[1] Generator unexcited.

COMMENTS

45 The table on next page shows the economical results of the tests of the non-condensing engines:

46 There are several striking features in these results, as follows:

a The most important is that the four valve engines, which were built to be more economical than single valve engines, have utterly failed in their object. No. 4 engine had steam superheated some 20 deg. fahr., and this gave the engine a great advantage over any other tested. These results show that efforts to realize economy by duplication, or multiplication, of parts, even if ports are shortened and clearances reduced, accomplish nothing. The duplication of valves used in both four valve engines simply increased the opportunity for leakage. In Engine C, the exhaust valves probably were tight and as far as possible minimized the effect of the probable very large leakage by the inlet valves.

After considering these tests, we do not hesitate to advise builders to abandon four valves for high speed engines unless they are prepared to build a really high class engine having four Corliss or gridiron valves, made and fitted in the best manner. Even then it would be necessary for them to prove their case. Steam engines of whatever type should have valves that are not only tight originally, but that should become so by wear if they are not so originally. The wearing process should be a tightening process.

b Comparing the results of the flat valve engines, the most economical results were obtained from Engine No. 3, which had a valve which automatically takes up wear, and if it does not cut, must maintain itself tight for long periods. The valve of this engine is evidently its saving feature, for the port system could hardly be worse for realizing economy. The ports are long and tortuous, have great surface and the clearance volume must be large.

c Comparing the piston valve engines, there is little reason for one being superior to the other, although Engine A surpassed Engine B in economy. Engine B has considerable unprotected surface on the steam chest and this must increase condensation.

Engine.	Duration of Service.	¼ Load	½ Load	¾ Load	Full Load	1¼ Load	1½ Load
	Hrs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
No. 1 One Flat Valve	15 216		38.5 per i.h.p. 37.2 per i.h.p. 62.3 per kw-hr. 60.2 per kw-hr.	36.2 per i.h.p. 58.4 per kw.			
No. 2. One Flat Valve	20 000		36.7 per i.h.p. 66.0 per kw-hr.		35.8 per i.h.p. 59.7 per kw-hr.		
No. 3 One Flat Valve	28 644		31.7 per i.h.p. 57.1 per kw-hr.		32.0 per i.h.p. 57.4 per kw-hr.		
No. 4 Four Flat Valves	719		39.6 per i.h.p. 59.8 per kw-hr.	37.5 per i.h.p. 54.9 per kw-hr.	36.7 per i.h.p. 54.7 per kw-hr.		
A One Piston Valve	32 000		39.75 per i.h.p. 61.76 per kw-hr.	34.67 per i.h.p. 51.80 per kw-hr.		29.53 per i.h.p. 43.42 per kw-hr.	
B One Piston Valve	5 600	52.0 per i.h.p. 96.7 per kw-hr.	40.7 per i.h.p. 64.8 per kw-hr.	36.3 per i.h.p. 55.2 per kw-hr.	33.55 per i.h.p. 49.4 per kw-hr.		
C Two Flat Inlet Valves Two rotating exh. valves	10 800		44.02 per i.h.p. 79.30 per kw-hr.		36.7 per i.h.p. 60.48 per kw-hr.		34.10 per i.h.p. 53.74 per kw-hr.

d Comparing the flat and piston valve engines, if we do not consider the loads, the most economical result was obtained from a piston valve engine. This result was, however, obtained when the engine was heavily loaded. With the lighter loads that are comparable the flat valve Engine No. 3 surpassed Engine A in economy. Moreover, the flat valve engines give a flatter load curve than the piston valve engines, which is a valuable feature.

e The performances of the perfectly balanced flat valve engines are so relatively poor, that it seems to disqualify them, unless this type of valve can be made with some mechanism by which wear will not increase leakage. Possibly metal strips might be used in a manner similar to that employed in the Richardson valve. It must be difficult to keep a shop force up to the pitch required to fit these valves, balance plates, and distance strips properly. It is doubtful, in fact, if this type of valve is tight even when new, and it has no chance of ever being tight thereafter unless it is re-fitted, which is seldom done. This type of valve must take the whole responsibility of the extravagance of the four valve engines. Engine No. 1 had the advantage of steam superheated 7 deg. fahr. to 14 deg. fahr.

f The results show that heavy loads with high speed engines give the most economical results, and this confirms the statement of D. K. Clark in the early fifties that the most economical point of cut-off in locomotives is at about one-third stroke. This was again substantiated by Professor Goss with the experimental locomotive at Purdue University.

g One interesting thing about the results is that no stationary high speed engine is as economical as passenger locomotives that are in good order. We expect that such locomotives will use as little as 26 lb. of steam per indicated horse power per hour, and better results have been obtained. This economy was realized before very high steam pressures were used.

h It is unfortunate that the tests were not of greater duration, but the results would probably not have been thereby materially different. Moreover, the results accord very well with what might be anticipated. The difficulty of

making the tests at all and the importance of obtaining the results as soon as possible are the excuses for the shortness of the tests. It should be stated, however, that some of the tests were of greater durations than given, which are those during which permanent rates were established.

i In regard to the relative economies of flat and piston valve engines, I am inclined to believe that the former are the more economical, if the valves are self-adjusting with wear, and are of a good design. They must have less port surface and less clearance, and can be made to adjust themselves for more wear than piston valves.

j Persons who are familiar with guarantees of steam consumption which accompany sales of high speed engines are aware that these guarantees are usually met in shop tests, but these tests show that no engine realized economies which would have been guaranteed. From the results we are justified in thinking that most high speed engines rapidly deteriorate in economy. On the contrary slower running Corliss or gridiron valve engines improve in economy for sometime and then maintain the economy for many years. It is difficult to see that the speed is the cause of this, and it must depend on the nature of the valve.

THE SURGE TANK IN WATER POWER PLANTS

A DEVICE FOR AID IN SPEED REGULATION AND PRESSURE RELIEF IN WATER POWERS WITH LONG PRESSURE PIPES AND HIGH VELOCITIES

By Raymond D. Johnson, Albany, N. Y.

Non-Member

INTRODUCTION

I have prepared this paper at the request of Mr. John R. Freeman and as an outcome of certain practical problems which I have assisted him to treat mathematically and which arose successively in planning three large hydro-electric developments. Therefore, although some may regard the paper as overflowing with equations and calculus, I trust it will nevertheless be regarded as practical.

2 "Surge Tank" is a term applied to a stand pipe or storage reservoir placed at the down-stream end of a closed aqueduct to prevent undue rise of pressure in case of a sudden diminution of draft, and to furnish water quickly when the gates are opened, without having to wait for the velocity in the long feeder to pick up. When such a device terminates a pipe used to feed water wheels, the changes of load, producing corresponding variations in gate opening, cause the stored water to rise and fall in wave-like swells or "surges;" hence the name. It has long been recognized by hydraulic men that a storage pond or artificial lake at the end of an aqueduct serves to remove harmful results of sudden changes in draft which would otherwise give rise to undue pressures, known variously under the names of "water-hammer," "breathing," "surging," etc., according to the nature and intensity of the pressure waves. So far as I know,

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however, no attempt has previously been made to proportion such a reservoir economically and accurately. This I have tried to do.

3 I have also gone a step further in pointing out the efficacy of the differential principle, whereby the area of the reservoir is lessened by 50 per cent and the regulation is markedly better. This principle is named from its action in differentiating the "pressure water" from the "stored water," which are identical in the ordinary tank. That is, the level in the tank is *both* the accelerating level, which urges the water to flow faster or slower in the conduit, *and* the level of the "stored water" as well. It is clear that the velocity in the conduit cannot be altered unless and until the level changes in the tank, and that the rapidity of such velocity change is proportional to the amount of such level-change. It therefore follows that the capacity would have to be much greater than it would if the accelerating head could instantly be applied to the pipe, without having to wait for the water level to be drawn down.

4 This desirable result can be had by drawing the water from the tank through constricted openings of fixed size, properly proportioned. A forced loss of head is thus effected, causing a sudden change in the accelerating level to a value which holds constant during the period of velocity change and until the level in the tank becomes coincident with the level represented by the accelerating head, which coincidence obtains simultaneously with the acquirement of the new velocity value as demanded.

5 The importance of a proper study of this subject was from time to time brought forcibly to the attention of Mr. Freeman when inspecting certain of the recent large water power plants in the West and in Mexico, where in a dry country water was almost continually wasted in order to regulate the speed of the water wheels, under their varying loads. In certain of his own designs he departed from the ordinary methods, in order to prevent waste of water and all needless waste of fall, and planned to use the water at high velocity through long pressure tunnels under the full mill pond pressure. He provided for a surge shaft and surge reservoir close to the power house for the relief of the pressure due to arrest of motion of the great mass in the moving water column or for a momentary supply in case of increased demands while the elastic wave was transmitting the demand for more water back to the conduit entrance and overcoming the inertia of the water column.

6 It was easy to see that with a large surge reservoir near the power house this method would be simple and effective; but a large

surge reservoir would be very expensive, and it appeared somewhat difficult to tell just how small this surge reservoir could be made without the sacrifice of quality of speed control. Also, on a canyon-side or in other situations where natural support for a great weight at the proper elevation is lacking, the problem of minimum size for the surge tank becomes of great importance.

7 It may be stated at the outset that it is seldom or never necessary to waste any water in speed regulation, and it is usually very undesirable to do so. Governor-operated by-pass valves and deflecting nozzles have seldom an excuse for existence except, perhaps, in instances where a choking of the turbine feeder would overflow the sides of an open flume and waste in any event; but with closed pipes feeding the wheels, however long, there need never be any substantial waste of water for regulation or pressure relief. It is, moreover, exceedingly cheap to effect this saving.

8 It is always more convenient, if there is high lying ground near the power house on which to locate the surge tank so it may be operated under atmospheric pressure; but usually the dimensions of the tank are so small that it is feasible to locate it at any convenient lower level, even directly adjacent to the power house if necessary, by simply increasing the air pressure by closing in the top of the chamber and connecting it to a compressed air tank of adequate though comparatively small dimensions.

9 Where there is high lying ground somewhat remote from the power house, an atmospheric regulator may there be installed, and then, if the length of closed pipe between this point and the power house is too great to permit good regulation, a small secondary auxiliary compressed air regulator may be placed adjacent to the power house. These two will work together perfectly, each attending to its own length of conduit.

10 I will not describe the several possible forms and details of surge tank regulators at this juncture, but, in order to make clear the conclusions which I have reached, will simply express forcibly my belief that any form of turbine governing device which uses as its chief means of speed control the waste of valuable water, is, in general, a bad design and so far as I can at present see, ordinarily unwarranted and unnecessary.

CONCERNING CERTAIN POPULAR MISCONCEPTIONS

11 If excuse is needed for presenting this paper, it can be found in the published statements of certain experienced hydraulic engineers, and in the design of certain otherwise admirable plants.

12 For example, the writer has recently noticed in Mr. H. E. Warren's very able article written for the Lombard Governor Co. only a year ago, a statement in reference to the effect of long pressure conduits upon regulation, that "The only complete remedy for the troubles in speed regulation caused by excessive inertia of a water column is some form of by-pass valve directly connected with the water wheel gates, arranged to open as the gates close, and thus keep the velocity of the column nearly constant." When such a statement is published by people who make water wheel regulation a business and have an excellent reputation for success, it is well to demonstrate the possibilities of an opposite course.

13 The remedy of a by-pass as suggested is wasteful of valuable water which would otherwise be storing up in the pond. It will be shown that speed regulation is possible without a by-pass and its waste. The article cited further states that "Although it is possible to prevent excessive rise of pressure due to reduction in velocity of long water columns, no means have been devised to produce quick acceleration of the water when, because of a sudden increase in load the speed of the turbine begins to fall." The writer believes it can be demonstrated that this statement is not altogether correct and will describe a form of differential regulator such as to provide acceleration "quick" enough so that by the time the automatically stored water is used up, the velocity in the long pipe will have acquired its new demanded value. This paper is intended to elucidate the mathematical theory of such action. Since the theory of this device was worked out some 6 years ago, the writer perhaps ought to apologize for not sooner presenting it to his fellow designers for their criticism and suggestions.

14 The problems of water turbine governing will not be treated in this paper, as will later become apparent, but the argument will be confined to showing how simple it is to automatically regulate the acceleration and retardation in a long column of water so that the difficulties in turbine governing largely disappear.

15 It is never required of a large plant to furnish a sudden increment from zero to full load, or anything like it, although with a proper surge tank this could be easily done with no more than 10 per cent variation in head in a 5000 foot feeder at 8 ft. velocity, if desired, instead of a variation of some 160 per cent as stated in the paper cited as being unavoidable. As a matter of fact, all that would be necessary, if the topography of the country was such that an elevation equal to that of the pond water could be had within a reasonable distance of

the power house, would be to install a small tank, of less than three times the diameter of the feeder pipe. For example, in the case cited in the paper referred to, the pipe was 5 ft. in diameter, in which case. the regulating surge tank need be no more than 15 ft. in diameter, and the cost of this is obviously a small matter if it is successful in reducing changes in head from 160 per cent down to 10 per cent of the assumed head of 400 ft.

FUNCTION OF A STAND PIPE

16 Where the topography of the country is not such that a high elevation can be had near the power house, compressed air must be resorted to as will be later pointed out.

17 Let us briefly review just what the function of a stand pipe is, and how it operates to supply water to the wheels while the long conduit is changing its velocity from a lower to a higher value as demanded by a change in load at the power house.

18 To be most effective ,the stand pipe or surge pipe should be located as near the power house as possible. It is usually placed at the end of the conduit or main feeder, and is sometimes formed by simply turning up the end of the conduit, into a vertical or inclined position, and extending it up to a level somewhat above that of high water in the forebay or storage pond.

19 The penstocks or individual water wheel feeders are led out of the main feeder at points as near as possible to this stand pipe. Where steel penstocks or wood stave pipe bound with iron hoops are used, plants are laid out, where possible, so that the greater part of the total drop occurs between the end of the main conduit and the power house, thus keeping the pressures in the main conduit as small as possible and permitting the emergency gates at the heads of the individual turbine feeders to work under moderate pressure. Care is also taken to have these separate turbine feeders as short as practicable.

20 Now, with this arrangement, when the water wheels are running under a constant load, it is clear that the water level in the stand pipe will be stationary at an elevation below pond level equal to the friction head in the conduit, and this level will represent the effective head on the wheels, if the friction losses in the turbine feeders be for the moment disregarded.

21 Let us study in a casual way the cycle of phenomena following a sudden demand for more water by the wheels:

(*a*) We have assumed a conduit so long that acceleration in it is far too slow to meet the sudden demand for more water within any reasonable time, and therefore, momentarily the additional water required nearly all flows from the stand pipe, thus depressing its level.

(*b*) This depressed level being below the end of the hydraulic gradient due to the existing velocity, a lessened pressure is transmitted back to the pond with the velocity of an elastic wave or the speed at which sound would travel in water, about 4500 ft. per second. This quickly produces an accelerating head which begins to increase the velocity of the water in the conduit.

(*c*) The water level in the stand pipe continues to drop and the velocity in the conduit to increase until such increased velocity value becomes equal to the new demand for power. The larger the stand pipe area, the less the level will have become depressed before this condition is reached, and therefore the less the variation in head that will be felt at the water wheels.

(*d*) The stand pipe level, meanwhile, will have been drawn much below the elevation of the end of the existing velocity gradient, so that a greater acceleration than necessary in the conduit will be caused and must continue. The level in the stand pipe therefore soon begins to rise and more water soon begins to be supplied than is being used by the turbines even under the increased load.

(*e*) The conduit velocity continues to increase until the water level in the stand pipe has risen to an elevation identical with that of the end of the velocity gradient existing at that time, after which it begins to be retarded as the stand pipe level continues to rise.

(*f*) The maximum elevation is reached when the surplus energy created in the conduit by the first depression of level is reconverted into potential energy represented by this temporary maximum elevation of water in the stand pipe. Meantime, retardation of the conduit velocity continues, until

(*g*) The elevation of the water again becomes coincident with the end of the velocity gradient.

Neglecting for the moment the complications induced by the efforts of the turbine governor this completes a description of one complete

cycle of the pressure wave, which goes on repeating itself indefinitely until smothered by the action of friction.

RESULT OF THE TURBINE GOVERNOR'S EFFORTS

22 Before going further we may take time briefly to consider in a general way the possible dangers of a stand pipe of ordinary form not much larger than the conduit.

23 Where such a device terminates a long closed flume, it is clear that any demand for additional load in the power house will have to be fed primarily, and almost wholly, from the water contained in the stand pipe. This creates a depression in the water level which in turn begins to accelerate the main column of water in the feeder. Now if there were no friction affecting this column there would be not only an ultimate recovery of the water level (which would be the equivalent of a pendulum returning to a vertical position), but there would be a subsequent surge of the water to a level as much above the original level as the depression was below it. If this surging were plotted with time it would give a perfect sine wave, which without friction loss, would never cease when once started by an increment of load. The effect of friction is to increase the throw of the first depression but to decrease in greater proportion the subsequent surge in such a way as to produce a damped harmonic which of course practically dies out pretty soon.

24 With a long conduit, a mile or more in length, these oscillations are comparatively slow, occupying sometimes more than one or two minutes for a complete oscillation, so that any ordinary water wheel governor has no difficulty in keeping step with the wave, gradually closing the gates as the head increases and opening them, conversely, in an effort to keep the product of velocity, or cubic feet per second, and head nearly a constant quantity. This essential and unavoidable action of the governor may lead to astonishing results, on account of which the ordinary stand pipe might prove almost worse than useless.

25 Returning to our first harmonic curve where friction was neglected, let us consider for a minute the effect of this governor action upon such a wave. It must be obvious that the further opening of the gates as the depression in level takes place will have the effect of increasing the amount of such depression. Now, without any closing of the gates, the surge will raise the level an equal distance above normal; but when we consider that the gates must close as the pressure rises, it is clear that the wave will rise a greater amount than

it fell, and so *go on in an ever swelling harmonic*, ceasing to increase only when it reaches the top of the surge pipe and spills over. Then, after continuing to spill for some time, it will return in another dip only to rise again and spill some more, thus continuing to spill over at regular recurring intervals so long as the load holds steady.

26 Thus far we have been neglecting friction in this last argument. A little thought at this juncture will lead one to a natural conclusion that if the swelling effect, due to the governor action, exceeds the damping effect, due to the action of friction, *the harmonic will swell in spite of the friction* and this is precisely what will take place *if the stand pipe area is below a certain critical amount* which is mostly a function of the length of the conduit.

27 This unstable condition would make operation practically impossible, and it is an extremely easy thing to bring about such a condition by simply being a little careless in the choice of a regulating device. Furthermore, it does not necessarily follow that the stand pipe area is sufficient simply because it is larger than this critical size. This is more likely to be true for high heads than for low heads, but often the variation in head due to throwing on or off part load may be too great a proportion of the normal head, even though an increasing wave cannot exist.

28 To sum up, therefore, it is extremely dangerous to design a stand pipe of moderate size without going thoroughly into all the conditions which it affects, unless the load is to be particularly steady and the main feeder pipe pretty short. Where the feeder is more than a mile long the problem becomes tremendously important, and is worth a large amount of careful study.

29 As we develop the formulas for working out these problems, it will become apparent, as indeed common sense would indicate, that all the desired conditions may be fulfilled by simply making the stand pipe of sufficient area, so the whole matter resolves itself into a question of area and depth.

30 It will later be shown what a great advantage can be gained over the simple stand pipe or storage tank *by differentiating the pressure water from the stored water.* In practice, this may be easily accomplished by using a comparatively small stand-pipe or surge shaft which is contained within a larger tank, and communicating with it only by means of fixed ports or holes in the smaller pipe near the bottom of the larger one.

31 The small pipe may be at one side instead of within the tank and may communicate with it through a restricted by-pass of fixed size.

32 The action of such an arrangement is like that of a dash pot, and if properly proportioned it effectually damps any vibrations which would swell to undue proportions in an ordinary tank of twice the area, so that the cost of this style of combination regulator will usually be found not much more than one-half that of an ordinary simple storage tank of sufficient size to accomplish the same final result. Further, the regulation is much better, for there is little or no chance that bad conditions may result from throwing on loads at critical times such as to superimpose one wave upon another, as is quite possible with the simple tank.

THE MATHEMATICAL ANALYSIS OF THE PROBLEM

33 The best way to approach these problems is through equations of work and energy, and it may be as well to start out by laying down a perfectly general principle which will later become evident.

34 The work done within either the stand pipe or differential regulator, in raising or lowering the water, is precisely equal to the work of lifting the weight of the water in the conduit through a distance equal to the head due to the velocity lost or gained in the conduit, which change in velocity is in turn due to a change in load.

35 The work done within the stand pipe, neglecting all friction, would be $\frac{1}{2} y_1^2 \times \frac{A}{R} \times \alpha$ where y_1 = the maximum height of surge, R = the ratio of conduit area "A" to stand pipe area, α = the weight of water. The equivalent energy destroyed or gained in the conduit would be $\frac{(V_2 - V_1)^2}{2g} \times LA\ \alpha$ where L is the length of the conduit, $V_2 - V_1$ the ultimate change in velocity due to the load change.

36 Equating these we have

$$y^2 = \frac{RL}{g} (V_2 - V_1)^2 \text{ or } y = \sqrt{\frac{RL}{g}} (V_2 - V_1)$$

37 This formula neglects both friction and the bellows action of the wheel gates in keeping step with the wave. This latter consideration may usually be neglected if the regulator is *otherwise designed* correctly, but not unless. The equation given is not the equation of the wave curve, but simply an expression for y maximum. We will now develop the differential equation of this curve, still for the present neglecting friction and also work out the period or time of vibration of the water pendulum.

38. The work done upon the water in the tank when part load is rejected is $y\,d\,y\,\frac{A}{R}\,\alpha$: this may also be written in terms of the velocity change or $\frac{\alpha\,LA}{g}\,(V - V_1)\,d\,v$, whence we have

$$y\,d\,y = \frac{L\,R}{g}\,(V - V_1)\,d\,v$$

$$\int^{y} y\,d\,y = \frac{L\,R}{g}\int_{V}^{V_2}(V - V_1)\,d\,v$$

Solving for y we have

$$y_r = \sqrt{\frac{R\,L}{g}}\left\{(V_2 - V_1)^2 - (V - V_1)^2\right\}^{\frac{1}{2}} \qquad [1]$$

Similarly for accelerating, when part load is demanded we have

$$y_a = \sqrt{\frac{R\,L}{g}}\left\{(V_2 - V_1)^2 - (V_2 - V)^2\right\}^{\frac{1}{2}} \qquad [2]$$

39 The maximum value of y can be seen to be the same in both cases, or as previously demonstrated.

$$y_1 = \sqrt{\frac{R\,L}{g}}\,(V_2 - V_1) \qquad [2a]$$

40 To find the expression for time in terms of velocity we have

$$\frac{L}{g}\,d\,v = y\,d\,t$$

$$\frac{L}{g}\int_{V_1}^{V} d\,v = \int_{o}^{t} y\,d\,t$$

or substituting for the value of y from (1)

$$\sqrt{\frac{L}{g\,R}}\int_{V_1}^{V}\frac{d\,v}{[\,(V_2 - V_1)^2 - (V_2 - V)^2\,]^{\frac{1}{2}}} = \int_{o}^{t} d\,t$$

from which

$$t_r = \sqrt{\frac{L}{g\,R}}\left\{\frac{\pi}{2} - \sin^{-1}\frac{V - V_1}{V_2 - V_1}\right\} \qquad [3]$$

and similarly for accelerating by substitution from (2)

$$t_a = \sqrt{\frac{L}{g\,R}} \left\{ \frac{\pi}{2} - \sin^{-1} \frac{V_2 - V}{V_2 - V_1} \right\} \qquad [4]$$

We may now write the true equation of the wave curve by elimination of V between (1) and (3) or between (2) and (4) and we have, in either case the same equation.

$$t = \sqrt{\frac{L}{g\,R}} \left\{ \frac{\pi}{2} - \sin^{-1} \pm \frac{\sqrt{(V_2 - V_1)^2 - \frac{y^2\,g}{R\,L}}}{V_2 - V_1} \right\} \qquad [5]$$

This is the relation between time and wave elevation and hence is the equation of the true harmonic curve. For y maximum we have simply,

$$t = \sqrt{\frac{L}{g\,R}} \left(\frac{\pi}{2} + \sin^{-1} 0 \right) \qquad [5a]$$

41 This is a periodic function, and denotes the successive times when the wave reaches its crest.

$$t \text{ for } y = 0 = \sqrt{\frac{L}{g\,R}} \left(\frac{\pi}{2} + \sin^{-1} 1 \right)$$

which is also a periodic function and denotes the successive times when the wave passes through zero. It is interesting to note that where $R = 1$ the formula is identical with that for a simple pendulum as might have been guessed. That is, the time of complete vibration of this water pendulum of length L is $\pi \sqrt{\frac{L}{g}}$ where the stand pipe is the same size as the conduit. This time is precisely the same as for a pendulum of a length equal to that of the conduit, and is independent of the amplitude; that is, the amount of load thrown on or off cannot materially affect the period of surge.

COMPUTATIONS INVOLVING FRICTION

42 The introduction of friction into these computations leads to such difficult mathematics that it is almost necessary to resort to an approximation. This may be done in many ways which may be devised to order. I will set forth one of the most evident, and one

which leads to no appreciable error in any practical case, and which has the advantage of being comparatively simple.

43 Proceeding as before the work done within the stand pipe is no longer

$$\frac{1}{2} y^2 \times \frac{A}{R} \times \alpha$$

when we take friction into account, but is

$$\frac{A}{R} \alpha \int_o^y (y - Z)\, dy,$$

where Z represents the change in hydraulic gradient and is equal to $C\ (V_2^2 - V^2)$ for retarding or $C\ (V^2 - V_1^2)$ for accelerating, C being the friction constant. The exponent 1.85 would probably be closer than 2 and may just as easily be used if desired. The expression is not as simple as before, for now we have

$$\int_o^y (y - Z)\, dy = \frac{L R}{g} \int_V^{V_2} (V - V_1)\, dv$$

$$= \int_o^y y\, dy - C \int_o^y (V_2^2 - V^2)\, dy$$

$$\int_o^y y\, dy = \frac{L R}{g} \int_V^{V_2} (V - V_1)\, dv + C \int_o^y (V_2^2 - V^2)\, dy$$

or

$$y^2 = \frac{R L}{g} \left\{ (V_2 - V_1)^2 - (V - V_1)^2 \right\} + 2 C \int_o^y (V_2^2 - V^2)\, dy \quad [6]$$

44 Now $V^2\, dy$ in the last term is extremely difficult to integrate. But we know something about the value of $C\ (V_2 - V^2)$ in terms of y; not much to be sure, but this at least, that $y - C\ (V_2^2 - V^2)$, which is the accelerating head, is positive in the first cycle up to the time V reaches its maximum value, when the expression changes sign and remains negative for half a cycle, etc. We know, also, that y reaches its maximum sometime before V reaches *its* maximum, and therefore that V reaches its maximum for a value of y between its maximum and 0. Also, the maximum of the accelerating head occurs practically at the same time as y attains its maximum. We may, therefore, write $C\ (V_2^2 - V^2) = X\, y$ where X is less than unity, up to the time V reaches its maximum, at which time it becomes unity. Now if we

put $X = 1$ and $V = V_1$, we shall obtain the value of y maximum within a small amount.

45 A still closer approximation may be made, if desired, by putting $C(V_2^2 - V^2) = b\,y^n$, where b and n are constants. These would have to be evaluated by tedious graphical methods, and would eventually be found to modify the value of y maximum so little as to render the labor futile. Putting $V = V_1$ and $X = 1$ in equation (6) we have

$$y^2 \text{ max.} = \frac{R\,L}{g}(V_2 - V_1)^2 + C^2\,(V_2^2 - V_1^2)^2 \qquad [7]$$

which holds good both for accelerating and retarding. The time to reach y max. will be a little *longer* than that given by equations 4, 5, etc., but may be obtained with considerable accuracy by increasing the time in the same proportion that y increases when friction is considered. Dividing equation (7) by equation (2a) we have

$$1 + C^2\,(V_2 + V_1)^2\,\frac{g}{R\,L}$$

and multiplying this into the time of oscillation we have

$$t = \frac{\pi}{2}\sqrt{\frac{L}{g\,R}}\left\{1 + C^2\,(V_2 + V_1)^2\,\frac{g}{R\,L}\right\}^{\frac{1}{2}}$$

This may be written more conveniently

$$t = \frac{\pi}{2}\sqrt{\frac{L}{g\,R} + \frac{C^2\,(V_2 + V_1)^2}{R^2}} \qquad [8]$$

From this we see that t is still more or less independent of the amount of load change, but is decidedly affected by the actual values of V_2 and V_1. Therefore, we shall have different times of oscillation for the same actual velocity changes when starting out from different existing velocities. Practically, however, the value of the latter term is usually so small that the time of oscillation is really not a great deal affected by the friction, almost always under 10 per cent in an actual case.

46 This expression serves either in acceleration or retardation. The times in the two cases would probably be slightly different, and may be more nearly approximated in the following formulae, which are derived from equations (9) and (11) and are in terms of y max. as found from equation (7)

$$t_r = \frac{L}{g\sqrt{\frac{C\,y_1}{\sqrt{2}} - C^2 V_2^2}} \left\{ \tan^{-1} \frac{V_2}{\sqrt{\frac{y_1}{C\sqrt{2}} - V_2^2}} - \tan^{-1} \frac{V_1}{\sqrt{\frac{y_1}{C\sqrt{2}} - V_2^2}} \right\}$$

$$t_a = \frac{L}{2g\sqrt{\frac{C\,y_1}{\sqrt{2}} + C^2 V_1}} \log_e \frac{(Z_1 - V_1)(Z_1 + V_2)}{(Z_1 + V_2)(Z_1 - V_2)}$$

where

$$Z_1 = \sqrt{\frac{y_1}{C\sqrt{2}} + V_1^2}$$

If reasonable numerical substitutions are made it will be found that t, t_r and t_a will be about the same in the three equations just given, seldom differing by as much as 5 per cent. The last two are based upon the fact that the introduction of a differential action due to the insertion of a surge pipe within a reservoir does not change the time of vibration, but only affects y, making it less in the proportion of 1 to 1 2, about. The friction itself does not make any enormous increase in the time, so that values found above will rarely exceed by 10 per cent those obtained from equation (5a).

THE DIFFERENTIAL REGULATOR

47 We now come to the development of the equations relating to the differential regulator. In one respect these are more readily determinable than the foregoing, inasmuch as the term containing the friction is easily integrated, but in order to get at the subject at all a preliminary assumption has to be made which is not quite true but which leads to insignificant and perfectly negligible errors.

48 This regulator as previously described, consists of a small stand pipe or riser communicating with a reservoir by means of fixed ports which compel a difference in level between the water surfaces in the two vessels when a change of load occurs. This initial separation of the two levels, due to the constriction at the ports, is so sudden as compared with the change of level in the *large reservoir* that it may be regarded as having existed previous to the load change, or as coming into existence simultaneously with the change of load, and having a value equal to the head required to force the excess or deficiency of water through the ports as designed. Furthermore, the level in the riser, once it has attained this value, will hold it through-

out the accelerating or retarding period of the main conduit, *always provided* that there is just the right reservoir area so that by the time the reservoir level catches up to the riser level, the velocity in the conduit will have attained its new required value. Now, therefore, if we are going to wind up with the area accurately figured, we make no appreciable error in assuming the pressure level in the riser to be *constant* during the time the conduit velocity is picking up, and the excess water required by the wheels is being drawn through the ports from the reservoir.

49 That this condition of things actually does exist the writer has proven many times by a process of arithmetical integration; that is, computing the various curves representing changes in velocity, pressure head and friction head, by dividing the time into short spaces, say seconds, for these long swings, and laboriously computing, second by second the successive values of acceleration, velocity, pressure level, friction head, water wheel draught as the head varies, etc., thus integrating arithmetically all the various curves at the same time. This process is so obvious to anyone conversant with the ordinary physical laws, simply requiring a lot of patience, that it would be out of place here to go into a detailed description of the method. Let it suffice to say that *this method has one great advantage over calculus manipulation in that it makes possible the consideration of many more interdependent variables* than could be handled by any ordinary man with his limited knowledge of calculus, and the writer is not really sure that the man lives who would not if relying solely on the calculus sooner or later have great difficulty in dealing with these multiplex phenomena. If the writer had not repeatedly proven up his equations by just such tedious processes he would not now have the temerity to publish them.

50 Using the same nomenclature as before, and putting y max. $= y^1$ which as explained we are going to regard as constant, we have for retarding

$$d\,t = \frac{L}{g} d\,v \div [\, y_1 - C\,(V_2^2 - V^2)\,] \qquad [8a]$$

$$\int_o^t d\,t = \frac{L}{g} \int_{V_1}^{V_2} \frac{d\,v}{y_1 - C\,(V_2^2 - V^2)}$$

which is readily integrable and which gives an expression for the time it takes for the velocity to be retarded from V_2 to V_1. Integrating we have

$$t_r = \frac{L}{g\sqrt{Cy_1 - C^2 V_2^2}} \left\{ \tan^{-1} \frac{V_2}{\sqrt{\frac{y_1}{C} - V_2^2}} - \tan^{-1} \frac{V_1}{\sqrt{\frac{y_1}{C} - V_2^2}} \right\} \quad [9]$$

Now if we multiply both sides of equation (8a) by RV we have

$$R \int_o^t V\,dt = \frac{R\,L}{g} \int_{V_1}^{V_2} \frac{V\,dv}{y_1 - C\,(V_2^2 - V^2)}$$

but

$$R \int_o^t V\,dt - R\,t\,V_1$$

is evidently the height which the water rises in the large reservoir, and since by hypothesis we are going to make the value of R such that this height will be equal to y_1 we may equate this expression to y_1, thus

$$y_1 = \frac{R\,L}{g} \int_{V_1}^{V_2} \frac{V\,dv}{y_1 - C\,(V_2^2 - V^2)} - R\,t_r\,V_1$$

which becomes after integrating and simplifying.

$$y_1 = \frac{R\,L}{C\,g} \log_e \sqrt{\frac{y_1}{y_1 - C\,(V_2^2 - V_1^2)}} - R\,t_r\,V_1 \quad [10]$$

in which t_r is known from equation (9). This equation must be solved by successive approximations, but may be assisted very materially by remembering that

$$y_1 = \sqrt{\frac{L\,R}{2\,g}\,(V_2 - V_1)^2 + C^2\,(V_2^2 - V_1^2)^2} \text{ nearly,}$$

which may be directly solved, and the value of y_1 thus found may be substituted in (10) as a first trial.

51 The size of the ports will be determined later from a consideration of demanded loads rather than rejected loads. It is almost always true, however, that when the ports are properly designed for picking up as large part load as will ever be required, they will be *small* enough, so that in case of a sudden complete shut down, the water will easily attain its full figured height of y_1 in the riser, and even spill over into the larger vessel. It should always be arranged to do so, at any rate. The method of fixing the size of ports will be pointed out later.

52 As above, we have for acceleration,

$$d\,t = \frac{\frac{L}{g}\,d\,v}{y_1 - C\,(V^2 - V_1^2)}$$

from which, by integration as for (8a) and substitution between the proper limits V_1 and V_2 we have, after simplifying

$$t_a = \frac{L}{2g\sqrt{C\,y_1 + C^2\,V_1^2}} \log_e \frac{(Z - V_1)\,(Z + V_2)}{(Z + V_1)\,(Z - V_2)} \qquad [11]$$

in which Z is substituted for

$$\sqrt{\frac{y_1}{C} + V_1^2}$$

to save repetition.

53 Also, by a process precisely similar to the one for obtaining equation (10) we have

$$y_1 = R\,t_a\,V_2 - \frac{R\,L}{C\,g} \log_e \sqrt{\frac{y_1}{y_1 - C\,(V_2^2 - V_1^2)}} \qquad [12]$$

in which the same approximate value of y_1 as given for equation (10) may be used as a first trial, and in fact, is often close enough without going further.

54 The size of the ports is easily made consistent with the rest of the design by arranging them of such size as to discharge a quantity of water equal to $A\,(V_2 - V_1)$ under the head of y_1 Within reason-limits there is not much danger of getting them too large and it is always better to err on that side by assuming a value for $(V_2 - V_1)$ fully as large as can ever conceivably be suddenly demanded by an increment of load. $(V_2 - V_1)$ equal to 10 per cent V_2, where V_2 is the full load velocity, is often an outside figure for very large plants, but not for small ones.

55 Thus far not much account has been taken of the swelling action due to the *opening* of the wheel gates during depression of the wave, due to the drop in head, and the *closing* of the gates during surge of the wave due to rise in head. As before stated, this action is unimportant only when the design of the regulator is perfectly adequate in other respects, but it is always best to choose $V_2 - V_1$ large enough by making V_2 large enough to cover the increase in velocity

due to the dropping off in head equal to a trial y_1, which would tend to increase V_2 to about $\frac{h V_2}{h - y_1}$ where h is the working head.

56 This consideration increases in importance as the tunnel or conduit becomes longer, and for values of R above a certain critical amount, an inverse function of the length, the waves will accelerate at each vibration, and continue to increase in amplitude until checked by the open top of the surge pipe, after which they will vibrate at constant amplitude indefinitely, so long as the load remains steady.

57 The critical value is difficult to express mathematically, but it evidently may increase as the working head increases and must decrease as L increases; also, it is independent of the amount of initial change in load, and practically independent of the actual velocity values, within working limits. The following empirical expression is at least rational:

$$R = \frac{K h g}{L}$$

where K is nearly constant. It is probable that R ought never be less than unity. This expression is crude because it involves no consideration of friction; it is the best available, however, at the present writing.

58 It is true that many plants are in successful operation where the stand pipe is smaller than the feeder, but this is because the feeder is short so that the momentum of the rotating machinery holds the speed fairly steady during acceleration of the water column, without making it necessary to open the gates proportionate to the drop in head; or in other words, the dash pot action of the governor to prevent racing also prevents the gate opening keeping step with the pressure wave, and hence is contrary to the hypothesis upon which we have all along been reasoning.

59 The above formula therefore applies only to conduits which are of such length that the period of vibration is slow as compared with the speed requirement of the governor for good regulation. In general, where surge tanks are necessary at all, the formula will hold good.

60 After some computations by means of arithmetic integration the writer would give K the value of about $\frac{1}{2}$ where L and h are in feet. $R = \frac{h g}{E 2}$ from which R may be found. It *does not by any means follow* that this value of R will make the stand pipe large enough

to meet the requirements of regulation, but should be consulted only after all other conditions are satisfied, to see whether the succeeding waves are likely to be greater than the first one; if this value of R should happen to be smaller than that computed by the foregoing formulæ, then it should govern. If the value of R is made very close to the probable critical value as given above, it would be best to work out the wave second by second to make sure that it dies out.

61 With a proper differential arrangement the value of R could be twice as much as this critical value, and even then it would likely be way on the safe side. This consideration, however, is not of much practical value because almost invariably such a large value of R would make the head variation too great to meet the requirements of good regulation: but without the differential action it is quite possible to get R too large, especially when the head is low as compared with the length of the conduit. When $\frac{h}{L}$ gets below $\frac{2}{g}$ with L greater than a quarter of a mile or so, it becomes extremely easy to fall into grave errors, if no more thought is given to the size of the stand pipe than simply to provide area enough to prevent water hammer, which is sometimes done.

62 In computing R it must be borne in mind that the area of stand pipe which affects these pressure waves is that intersected by a horizontal plane. That is, if the pipe is not vertical it is more effective because the area of the horizontal ellipse is then what governs.

POSSIBLE USE OF COMPRESSED AIR

63 When the ground in the immediate vicinity of the power house is low lying, making it a hardship to carry the regulator structure as high as would be necessary, it is quite feasible and easily practicable to cut down the height by superimposing a false atmosphere of more or less high pressure.

64 This can be done by closing the reservoir at the top and connecting it to a compressed air chamber, providing a fairly ample expansion area. The compressor plant would be insignificant as it would merely have to make up for leaks and absorption of air by the water. The same formulæ apply pretty well when they are patched up and to allow for the expansion and contraction of the air.

65 Before developing equations for the design of the compressed air regulator, it may be well to point out a new phase of the differential action, as effected by the presence of the internal surge

pipe or riser. This pipe is really nothing more nor less than a piezo meter, or *measurer* of the accelerating or retarding head acting upon the conduit. Now, this head would exist, whether it were *measured* or not, so we may imagine the riser to be suddenly constricted indefinitely, just above the ports, but having ample entry way from the conduit. Then we may go a step further, and close up the pipe hermetically, just above the ports; and then, since the port holes may as well be horizontal as vertical, we may unite them into one hole at the termination of the short projecting neck of riser.

66 This gradually leads up to the use of a short nozzle entering the conduit, and leading, with ample entry way, from the bottom of the tank. Such an affair as naturally designed would provide far harder exit of the water from the tank into the conduit, than it would entry into the tank from the conduit, and this is precisely what is desired in the operation of a plant, because much larger loads, (even full load), are suddenly rejected than can ever commercially be suddenly demanded.

67 Even under atmospheric pressure the riser may sometimes be omitted to advantage, if the constriction at the port or ports makes the operation the same as though it were present, but usually it is better to have it in. The use of compressed air, however, would usually demand its omission, because the vertical dimension of the tank is almost never sufficient to furnish the required room for the water to rise and fall within it.

68 For an ordinary air tank without constriction at the ports we have $\frac{p\,l}{l-y} + y =$ the pressure head, where l is the length or height of the tank *above* the *water level*, or the length of the air column, p is the original steady air pressure in water-feed and y is the height of a wave, as before. The net head against which work is done in lifting the water and compressing the air is $\frac{p\,y}{l-y} + y$. Therefore, neglecting friction, we have,

$$\int_o^y \frac{p\,y\,d\,y}{l-y} + \int_o^y y\,d\,y = \frac{L\,R}{g}\int_V^{V_2} (V - V_1)\,d\,v \text{ for retarding.}$$

Integrating and simplifying we have,

$$y^2 - 2\,p\left\{ l \log_e\left(1 - \frac{y}{l}\right) + y \right\} = \frac{L\,R}{g}\left\{ (V_2 - V_1)^2 - (V - V_1)^2 \right\} \quad [13]$$

which becomes, for y_1 which is a maximum when $V = V_1$

$$y_1^2 - 2p\left\{ l \log_e\left(1 - \frac{y}{l}\right) + y \right\} = \frac{LR}{g}[(V_2 - V_1)^2] \quad [14]$$

which holds good for retarding. Similarly, for accelerating we have,

$$y^2 - 2p\left\{ l \log_e\left(1 + \frac{y}{l}\right) - y \right\} = \frac{LR}{g}[(V_2 - V_1)^2 - (V_2 - V)^2] \quad [15]$$

69 The time of vibration and the introduction of friction may lead to results by processes similar to those used in the previous solutions, but inasmuch as friction is usually negligible where compressed air is used, and the period of vibration has little practical value, I have not taken the time to go into these very tedious details. Besides, the differential action *should never be omitted.*

70 Let us now study this action under compressed air, and let "b" be the ratio of the instantaneous rise of pressure in the *imaginary* or *existing* internal surge pipe, to the ultimate maximum height of water wave, which we shall still designate as y_1. Let the value of R be such, that the ultimate rise of water to a value y_1 plus the additional pressure due to compressing the air will just equal the first temporary instantaneous rise of pressure which we are expressing as $b\,y_1$. If the value of R is eventually going to be fixed as above described, it follows that the retarding or accelerating pressure *level* will hold practically constant during the period of retardation or acceleration, and will have a value of $b\,y_1$ and the accelerating or retarding head will have a value of $b\,y_1 - Z$ where Z, as before, represents the change in hydraulic gradient.

71 The area of the ports to meet this condition must be

$$a = \frac{A\ (V_2 - V_1)}{\theta \sqrt{2\,g\,b\,y_1}}$$

where θ is the coefficient of discharge. Furthermore, inasmuch as we may have V maximum suddenly rejected and we may make the coefficient of nozzle discharge different, to suit, in exit and entry of water, it should be designed for two coefficients, θ' and θ'' for accelerating and retarding respectively, and we should have

$$a = \frac{A\,(V_2 - V_1)}{\theta' \sqrt{2\,g\,b\,y_a}} = \frac{A\,V_{max}}{\theta'' \sqrt{2\,g\,b\,y_r}} \quad [15a]$$

where $V_2 - V_1$ represents a large load suddenly demanded and V maximum represents full load suddenly rejected. Referring to equation (11) and putting $y_1 = b\ y_1$ we have,

$$t_a = \frac{L}{2\ g\ \sqrt{C\ b\ y_1 + C^2\ V_1^2}} \log_e \frac{(Z^1 - V_1)\ (Z^1 + V_2)}{(Z^1 + V_1)\ (Z^1 - V_2} \qquad [16]$$

in which

$$Z^1 = \sqrt{\frac{b\ y_1}{C} + V_1^2}$$

similarly to (11). Comparing equation (12) and introducing by_1 for y_1 in the right hand side of the equation, we have,

$$y_1 = R\ t_a\ V_2 - \frac{R\ L}{C\ g} \log_e \sqrt{\frac{b\ y_1}{b\ y_1 - C\ (V_2^2 - V_1^2)}} \qquad [17]$$

from which R may be found with a trial value for y_1 and b. The value of b has to be selected according to judgment, and is fixed entirely by the proportions of the air chamber and the air pressure as follows: According to the original assumption of the value of b,

$$\frac{p\ l}{l \mp y_1} \pm y_1 = \pm b\ y_1 + p$$

from which,

$$b = \frac{p}{l \mp y_1} + 1 \qquad [18]$$

and

$$l = \frac{p}{b - 1} \pm y_1 \qquad [19]$$

72 Note that b has slightly different values in accelerating and retarding due to change of sign. If y_1 and l are selected by judgment, then b follows, and R may be determined from (16) and (17). If the proportions do not suit, a new trial must be made, as there is no easy way to put these things together.

73 The decrease or variation in head on the water wheels, which is the thing usually desired to limit, is naturally $b\ y_1$ or, as above, for acceleration $\frac{-p\ l}{l + y_1} + y_1 + p$. So that b, l, and y_1 should really be

selected together according to judgment before attempting to work out t_a or R. Similarly, for retarding (c. f equations (9) and (10))

$$t_r = \frac{L}{g\sqrt{C\,b\,y_1 - C^2\,V_2^2}}\left\{\tan^{-1}\frac{V_2}{\sqrt{\frac{b\,y_1}{C} - V_2^2}} - \tan^{-1}\frac{V_1}{\sqrt{\frac{b\,y_1}{C} - V_2^2}}\right\} \quad [20]$$

$$y_1 = \frac{R\,L}{C\,g}\log_e\sqrt{\frac{b\,y_1}{b\,y_1 - C\,(V_2^2 - V_1^2)}} - R\,t_r\,V_1 \quad [21]$$

and for a complete shut down where $V_1 = 0$ and $V_2 = V$ maximum we have,

$$y_r = \frac{R\,L}{C\,g}\log_e\sqrt{\frac{b\,y_r}{b\,y_r - C\,V^2_{max}}} \quad [22]$$

in which y_r may be found by successive approximations, and when it is found, the value of θ'' may be determined from equation (15a), θ' having been determined from the assumed value of y_1 for accelerating. It is not absolutely necessary to have two values for θ, but this method is a desirable refinement. In presenting these formulæ for the design of regulators, it is desired to point out very clearly that the equations have not had the benefit of a thorough independent check—they are written rather hurriedly and if not absolutely right, as it is believed they are, the methods at least are correct and nothing more than a slip in algebraic transposition, or error in integration will likely be found. It is hoped that this presentation will call out all the necessary critics and checkers and clear the subject of all useless or erroneous matter.

74 The regulation is nearly as good with the air as without it if the differential feature is adhered to, but otherwise not. In such a case, the advantage of this feature is greater even than in the ordinary case.

75 The accompanying curves illustrate the difference in shape of the pressure wave between that produced in an ordinary open tank, and that produced under the same conditions when a small surge pipe is inserted within it. The periods are not quite the same on account of the reduction in the reservoir area due to the presence of the internal pipe. The quantities and constants assumed in working out these curves are as follows:

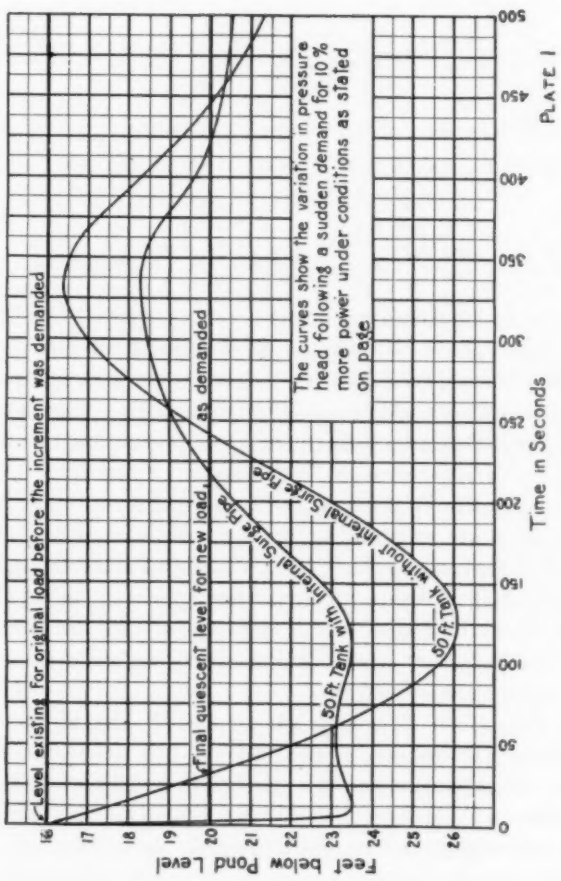
Level existing for original load before the increment was demanded
Final quiescent level for new load as demanded
Internal Surge Pipe
50 Ft. Tank with
Internal Surge Pipe
50 Ft. Tank without
The curves show the variation in pressure head following a sudden demand for 10% more power under conditions as stated on page
Feet below Pond Level
Time in Seconds
PLATE I

FIG. 1 COMPARATIVE PRESSURE WAVES IN OPEN TANK AND IN TANK WITH SMALL SURGE PIPE

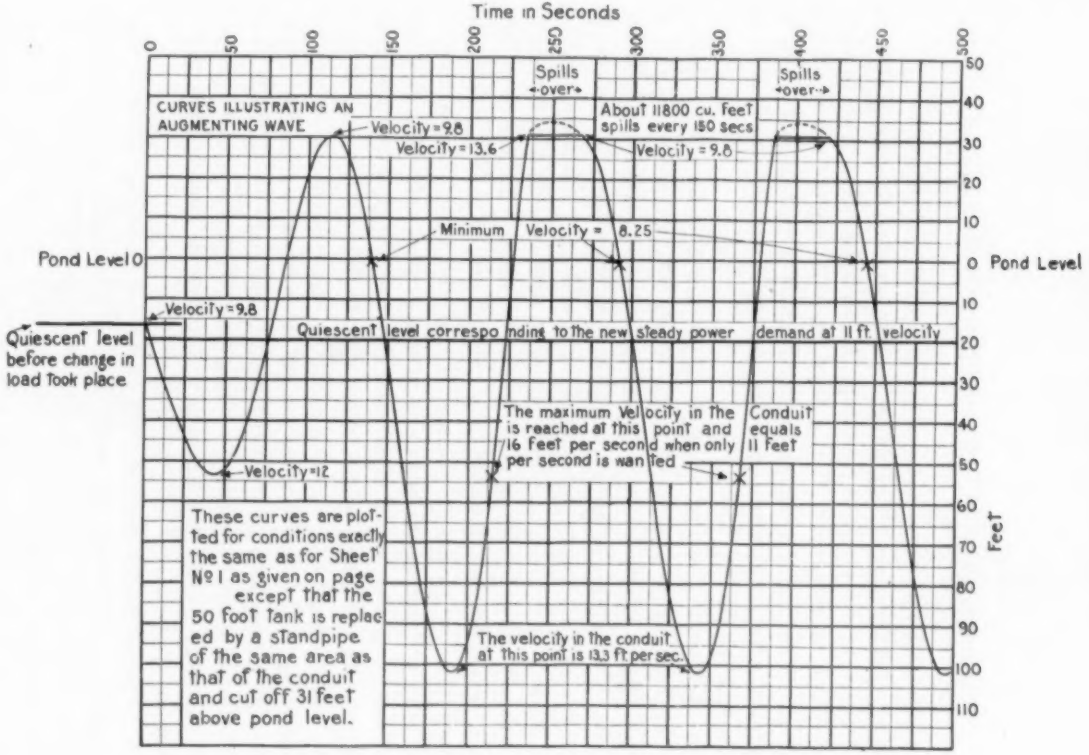
Time in Seconds
0
50
100
150
200
250
300
350
400
450
500
Spills over
Spills over
CURVES ILLUSTRATING AN AUGMENTING WAVE
Velocity = 9.8
Velocity = 13.6
About 11800 cu. feet spills every 150 secs
Velocity = 9.8
Minimum Velocity = 8.25
Pond Level 0
0 Pond Level
Velocity = 9.8
Quiescent level before change in load took place
Quiescent level corresponding to the new steady power demand at 11 ft. velocity
The maximum velocity in the Conduit is reached at this point and equals 16 feet per second when only 11 feet per second is wanted
Velocity = 12
These curves are plotted for conditions exactly the same as for Sheet No 1 as given on page except that the 50 foot tank is replaced by a standpipe of the same area as that of the conduit and cut off 31 feet above pond level.
The velocity in the conduit at this point is 13.3 ft per sec.
Feet
10
20
30
40
50
60
70
80
90
100
110

FIG. 2 PRESSURE WAVE WHERE STAND PIPE IS USED

$A = 220$ The diameter of surge pipe = 9 ft.
$R = 0.112$ " " " tank = 50 ft.
$L = 15200$ Aggregate area of ports = 20 sq. ft.
$V_2 = 11$
$V_1 = 9.8$
$h = 540$
Friction head 20 ft. for an 11 ft. velocity.

The action of the wheel gates is taken into consideration.

It may help give a practical flavor to this discussion to know that these particular curves represent conditions which would exist in the Feather River, Cal., development at Big Bend, in following out a design for a surge tank regulator as suggested by John R. Freeman, C.E., and as approved with some minor modifications by Viele, Blackwell & Buck of New York City.

76 Where it is desired to catch all the water under all conditions, the internal surge pipe has a particularly advantageous feature in permitting an effective factor of safety by simply extending it above the top of the tank, although the tank may have been figured not to overflow with the surge pipe cut off level with it. When the tank is not made ample to catch all the water in case of a shut down, some provision must naturally be made to carry it away. In case the differential action is used, however, it is usually just as cheap to catch all the water as to provide for getting rid of it, and a good deal neater.

77 The writer would like to point out emphatically that the subject matter of this paper is intended to treat only of the long and comparatively sluggish waves which vibrate in the main conduit as a unit, and *must not be confused with the rapid waves which serve to communicate pressure from one end of the column to the other.* The velocity of these latter waves is so great as compared with the time of oscillation of the surge waves, in a long conduit, that the time occupied in transmitting pressures through the column is neglected in all the foregoing studies.

78 Furthermore, adequate provision for damping these surges, according to the foregoing formulae, does not mean that regulation will be satisfactory *if the closed penstock between this regulator and the power house is too long or carries water at too great velocities* in proportion to the total working head and kinetic energy of the rotating machinery.

79 The closed turbine feeder or penstock also contains within itself two distinct classes of wave phenomena similar to the long main

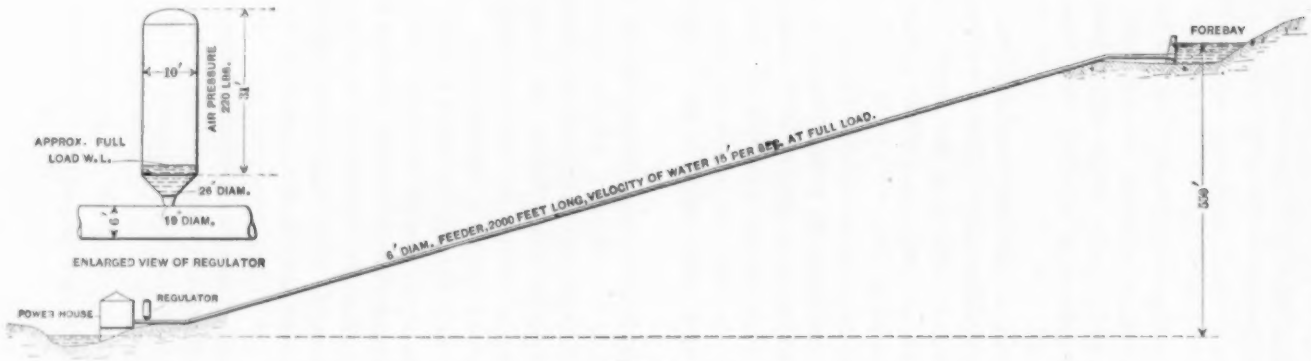

FIG. 3

Diagram showing the comparative dimensions of a compressed air differential regulator which will effect ideal control of the assumed 2000 ft. water column making the speed regulation of the water wheels commercially perfect under all conditions, by throlling the stream, without wasting any water. 25 per cent increments of load may be instantaneously demanded and almost instantly furnished by the governor, with less than 10 per cent drop in pressure and no appreciable speed variation, even though the fly wheel effect of the rotating parts is small. Full load suddenly rejected, at the probable rapid rate of governor travel, would not cause more than 30 per cent rise in pressure without relief valves.

conduit, but in this case there is usually not enough difference in time between the oscillating period of the surge wave and time of travel of the pressure wave so that the latter may be altogether neglected.

80 In the long conduit, the period of surge is a function of the length alone where R is constant; whereas, in the penstock, the period of surge is a function of the speed of the waterwheel governor which is too rapid to be considered as anything but infinite in the long conduit.

81 It is apparent then, that at least two considerations make the treatment of the closed penstock different from that of the long conduit, viz., the velocity of the pressure wave and the speed of governor travel which in the latter case are both regarded as infinite as compared with time of surge vibration.

82 The intimate relations between the kinetic energy in the penstock, the stroke of the governor, and the kinetic energy in the rotating machinery is not studied in this paper, as it would require more time to set forth than is at present available for the purpose; but the author would like to offer an empirical rule which is usually on the safe side, and often safer than is necessary, as follows.

83 If the length of the penstock is not greater than 18 times the head divided by the velocity, no difficulty will be exper enced in regulation, unless the load changes are abnormal as compared with the average plant. For very high heads where the wheel speed is likely to be high, this expression sometimes becomes altogether too safe but at any rate it may serve someone as a rough check.

84 If the conduit is, for any reason, extended beyond the penstock connections, before coming to the regulator, as is often desirable, then the effective length of penstock is increased, so far as regulation is concerned, and should be considered equal to $L' + R' L''$, where L' is the actual length of penstock, R' is the ratio of the aggregate penstock area to the area of the extension section, and L'' is the length of such extension.

85 The author will close this paper now with one or two numerical examples illustrating the application of his formulas.

Let us imagine a plant of following dimensions:

$$L = 5000 \text{ ft.}$$
$$A = 100 \text{ sq. ft.}$$
$$V_{max.} = 15 \text{ ft. per second}$$
$$C = \tfrac{1}{10}$$
$$h = 200 \text{ ft.}$$

The market or use for the power, is such, we will say, that we are likely to have sudden changes in load requiring an increment in velocity of, say 2 ft. per second, from 13 ft. to 15 ft. per second when the opening of the wheel gates and change in hydraulic gradient are considered. This amount or rate of change is a matter of judgment and must be estimated large enough for any particular plant and market according to the special requirements of the case, always remembering that larger part loads are likely to be rejected than demanded, except just after an accidental shut down when the reverse may be the case.

86 In selecting the increment in velocity it is better to use the high actual velocity values as giving slightly more unstable conditions. C should be chosen high enough to cover future deterioration of the smoothness, if necessary.

87 For this change in velocity of 2 ft. per second let it be required to keep the variation of head within 5 per cent., or say, not more than 10 ft. and in the first place let us figure the size and height of tank without any differential action. In equation (7) putting $y_{max.} = 10$ and solving for R we have,

$$100 = \frac{5000\,R}{32.2}(15 - 13)^2 + 0.01\,(\overline{15^2} - \overline{13^2})^2 \text{ or } R = \text{about } 0.11$$

Hence the proper area of tank $= \frac{A}{R} = 910$ or diameter $= 34$ ft.

88 Now let us see what the surge would be in case of a shutdown. To do this, put $V_2 = 15$ and $V_1 = 0$ in the same formula, and solve for $y_{max.}$ thus:

$$y^2_{max} = \frac{5000 \times 0.11}{32.2}(15)^2 + 0.01 \times \overline{15^4} \text{ or } y_{max} = 66 \text{ ft.}$$

which is to say that the water will rise 66 ft. above its existing full load level, which latter is $C\ V^2$ *below* the pond level, or $\frac{1}{10} \times \overline{15^2} = 22.5$ ft., hence the elevation of the top of the tank above the pond level must be $66 - 22.5$ or 43.5 ft. if it is desired to catch all the water after a shut down. This dimension will be on the safe side because all the water is never permanently rejected at the wheels, enough being retained to keep the runners up to speed. For this consideration it is obvious that a value of C should be chosen as low at least as it is likely to be in practice.

89 The total height of the tank is then, theoretically, 10 feet below the 13 ft. velocity gradient $= 43.5$ ft. above pond level or $10 + \frac{1}{10} \times \overline{15^2} + 43.5 = 70.4$ ft. In case of a complete shut down, regulation

is of no consequence, and care should be taken only that the pressures do not become unsafe. Let us now compare the dimensions of a tank containing an internal surge pipe 6 ft. or 7 ft. in diameter. The writer has found that within all reasonable limits the size of this pipe does not make much difference. It should be small for two reasons, economy and because with a small pipe the level takes its new position quickly and hence more nearly conforms to the theory upon which the tank dimensions are computed. It should be large enough so that the choking action due to it will not cause undue rise in pressure.

90 Reverting to formula (11) with $y = 10$ ft., $(V_2 - V_1) = (15 - 13)$, etc., let us solve for t_a or the time occupied in accelerating the water in the conduit from 13 ft. to 15 ft. per second, while the water in the surge pipe maintains a steady level 10 ft. below the end of the 13 ft. velocity gradient. This condition is very nearly brought about, as before pointed out, by giving such a size to the ports that they will discharge A (15 − 13) cubic feet per second under the head y or 10 ft. Therefore, if the coefficient of discharge is, say 0.6, we shall have the aggregate area of the ports,

$$a = \frac{A\,(V_2 - V_1)}{0.6\sqrt{2\,g\,y}} = \frac{100 \times 2}{0.6\sqrt{2\,g \times 10}} = 13.2 \text{ sq. ft.}$$

The ports may be a little smaller, and quite a lot larger without having much of any effect upon $y_{max.}$ In general, it is well, perhaps, to add some 5 per cent to the values thus obtained. Furthermore, the coefficient of discharge should be carefully considered according to the nature of the opening, the approach and exit of the water, and should be chosen as low as it is likely to be, as it is rather better to err on the side of too large "a" than too small.

91 To resume formula (11) we have

$$t_a = \frac{5000 \times 2.3}{64.4\sqrt{1 + 1.69}} \text{com. log} \frac{(16.4 - 13)\ (16.4 + 15}{(16.4 + 13)\ (16.4 - 15)} = 45.1 \text{ seconds.}$$

Now substituting this value in equation (12) we may solve for R thus

$$10 = R \times 45{\cdot}1 \times 15 - \frac{R \times 5000 \times 2.3}{3.22} \text{com. log} \sqrt{\frac{10}{10 - 0.1\,(\overline{15}^2 - \overline{13}^2)}}$$

The net tank area is therefore $\frac{1000}{6.244}$ or 410 sq. ft. as against 910 without the differential action. (These computations were made entirely on

the slide rule and are not particularly close). We have therefore made a saving of $\frac{5}{9}$ plus the additional small cost of the riser, without taking into account any change in height which we will now calculate. In order to catch all the water after a shut down let us revert to equation (10) and figure $y_{max.}$ with $R = 0.244$, $V_2 = 15$, $V_1 = 0$, etc. It will be noticed that the latter term vanishes and we have,

$$y = \frac{0.244 \times 5000 \times 2.3}{3.22} \text{ com. log} \sqrt{\frac{y}{y - 0.1\ (15)^2}}$$

This must be solved by trial, and as a first approximation solve for y in equation (7) as follows, putting $R = \frac{1}{2} R$:

$$y^2 = \frac{5000 \times 0.244}{64.4} (15)^2 + 0.01\ (15)^4 = \text{or } y = 69 \text{ feet.}$$

Substituting this above we have, $y = 872$ com. log $\sqrt{1.485} = 74.9$ from which we see that the trial value of y was too small so we now try $y = 71.5$ and we have $y = 872$ com. log $\sqrt{1.459} = 71.5$ which agrees with our assumption and is the correct value. The total height of tank and riser would be, as before $10 - \frac{1}{10} (\overline{15^2} - \overline{13^2}) + 71.5 = 75.9$.

92 In order to be sure that we have not carried the riser too high in proportion to the size of the ports we must see that their area is small enough so that water will be sure to reach at least the top of the riser. It is preferable to have it spill over into the tank which it will be sure to do if a is well under $\frac{AV_2}{0.6 \sqrt{2gy}}$ or when $a = 13.2 < \frac{100 \times 15}{0.6 \sqrt{64.4 \times 71.5}} = 36.8$ so in this case, as usually, spilling will be bound to take place, and our formula for $y = 71.5$ feet is on the safe side, for we have neglected the friction and choking heads of the high velocities in the riser due to shutting down full load, and disregarded the water necessary to hold the wheels at speed.

93 To sum up then, we can get better regulation and provision for catching energized water, with a tank 22.8 ft. diameter x 75.9 ft. high and a riser 7 ft. diameter x 75.9 ft. high than we can with a single tank 34 ft. diameter x 70.5 ft. high which would cost nearly twice as much.

94 The differential regulator is also better aside from the cost consideration, as already pointed out, because it has an increased

damping effect upon the surge waves after their inception, and renders less likely a troublesome condition due to coincidence of waves which would result from load changes occurring at critical times in such manner as to superimpose a wave upon one which was not yet dead.

95 In conclusion the writer would like to say that up to date he has had the benefit of very little criticism of his methods of treating these problems and is presenting this paper in the hope that it will interest a number of people sufficiently so that they will help to correct any errors which he may have, single handed, fallen into, and to expand and improve the mathematical treatment which has been developed without a particularly sound knowledge of differential equations.

NOTE. Patents have been applied for covering the differential feature of this device because the correct use of it requires careful study, and it is the hope that a certain amount of restraint in its use will serve better to control its proper application, and render less likely costly misuses which might reflect discreditably upon the whole idea.

NEW BOOKS

Members are invited to donate copies of their works to the Library. This is a custom generally followed by members of an association, and in the case of this Society, with its wide membership among technical writers, its observance would result in a considerable development of the up-to-date resources of the Library.

HYDRAULIC ENGINEERING. By Gardner D. Hiscox, M.E. A practical treatise on the properties, power and resources of water for all purposes, including the measurement of streams, the flow of water in pipes or conduits; the horsepower of falling water; turbine and impact water wheels; wave motors; centrifugal, reciprocating, and air-lift pumps, etc., etc. *The Norman W. Henley Publishing Company, New York, 1908.* 8vo, 320 p., 305 illustrations. Cloth, price 4.00.

Contents by chapter headings: Historical Sketch from the Earliest Times; Hydraulics, Properties of Water; Measurement of Flow of Streams; Flow from Subsurface Orifices and Nozzles; Flow of Water in Pipes; Siphons of Various Kinds; Dams and great Storage Reservoirs; City and Town Water Supply; Wells and their Reënforcement; Air Lift Method of Raising Water; Artesian Wells, Irrigation of Arid Districts; Water Power Water Wheel. Pumps and Pumping Machinery; Reciprocating Pumps; Hydraulic Power Transmission; Hydraulic Mining; Canals, Ditches, Conduits and Pipe Lines; Marine Hydraulics; Tidal and Sea Wave Power.

SOCIÉTÉ DES INGÉNIEURS CIVILS DE FRANCE. Mémoires et Compte Rendu, *Bulletin, February 1908. Vol 15,* 6th Series. 8vo., 292 p., 11 illus. paper.

INSTITUTION OF ELECTRICAL ENGINEERS. *Journal. Vol. 40, no. 188, April 1908.* 8vo., 452 p., 1 illus., paper.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS. *Proceedings. Vol. 27, no. 5, May 1908.* 8vo, 762 p., 3 plates, paper.

BULLETIN OF THE BUREAU OF LABOR. Department of Commerce and Labor. Washington. *No. 74, January 1908.* 8vo, 289 p., paper.

NEW YORK STATE EDUCATION DEPARTMENT. State Library Report 89. 1906. *Vol. 1 and 2,* 8vo, cloth, 590 and 249 p.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

011 Partner wanted to start a general engineering business in Chicago. Must be familiar with power plant equipment and electric installations, able to invest one-half the cash to put the company on a working basis. Give experience and references.

012 At opening of fall term, teaching position, paying $1400 to $1500, in charge of work in machine design; must be competent as machine designer; not important to have had experience in teaching, though preferred. Pleasing personality and strong character. Location near New York.

013 A copper smelting and refining plant in the East wishes to engage a superintendent of construction and repair; charge of ordering material and handling labor connected with this work. Must be well versed as a mechanical engineer in the construction and maintenance of buildings, furnaces and machinery and must be able to handle labor economically. It is thought that a man having had similar experience with steel works may be most readily able to meet the requirements.

014 First-class mechanical engineer, one experienced in fan business—heating and ventilating preferred, who would be willing to connect himself with a young concern which is placing on the market a line of these machines, that has proved in actual operation to be superior for this work. Location Missouri.

015 Young man, college graduate, mechanical and electrical engineer, one who has had both practical experience and some executive training. Location Pennsylvania.

MEN AVAILABLE

88 Graduate, mechanical engineering, Columbia Univ., 1904. Work in the construction field of engineering; at present engaged in general contracting work; anxious to change for a position in the commercial branch; would like to associate with sales department of engineering specialty or equipment house.

89 Draftsman, representative salesman or assistant superintendent along mechanical lines; location, immaterial.

90 Operating engineer of well known ability and reputation, member, inventor, now employed as steam and mechanical expert by large industrial concern and at present traveling in Europe, will consider engagement by July 1 with responsible concern where high class work and economy are essential. Location no object.

91 Marine engineer, member, whose experience covers a period of 29 years and a broad area, with practical and technical training, would accept position as port engineer or superintendent of steamship fleet.

92 Member with wide experience in manufacturing; will redesign, commercialize and manufacture meritorious mechanical appliances.

93 Junior, designer and draftsman, 9 years experience, special machinery, factory maintenance and equipment; 27 years old; prefers location in Boston district.

94 Hydraulic and mechanical engineer, age 36, member. Ten years experience in design, construction and operation of hydraulic power plants; ten years previous experience (in foreign countries) in general engineering and construction work. Well up in modern factory administration and organization, and competent in business affairs. Capable machine designer and salesman. Desires position with consulting or manufacturing engineers. Married.

95 Junior, mechanical engineer of 14 years experience in steam, hydraulic and machine lines; last four years superintendent of cement mill, would make a change.

96 Graduate, electrical engineering, Massachusetts Institute of Technology; experience, leading consulting and contracting engineering companies; large street railway company. Office and field designs, calculations, construction, tests and operation of steam electrical and hydraulic plants, apparatus and railway equipment.

97 Member of the Society, who for a considerable number of years has been in charge of all the mechanical design of construction in connection with the tunnel work of a railroad company located in New York City, is now open for engagement.

98 Graduate, Mass. Inst. of Tech., 1887. Two years as assistant in mechanical engineering, teaching drawing room and mechanical engineering laboratory; draftsman, mechanical engineer, on wide variety of shoe machinery, gasolene engines, steam automobiles and other special work. Superintendent of factory, manufacture cash and parcel carrying systems and pneumatic tube apparatus. Experience in the construction of manufacturing buildings and installation of steam and electric generating plants. Built and equipped with moulding machines a modern brass foundry, reconstructed a large electro plating department.

99 Member having 25 years experience, wants position of shop manager or general superintendent. Competent to take entire charge of factory. Expert in small interchangeable manufacture.

100 Member, mechanical engineer, familiar with every detail of power stations, coal handling, cement and industrial plants, familiar with up-to-date office management, can handle men and has good executive ability, wishes to change. Position in New York City, with consulting engineer preferred.

101 Member, located in Chicago, desires connection with first-class firm or consulting engineer. Has wide experience in construction, design and operation of large industrial plants, valuation and buying. Accustomed to handling large quantities of business economically and rapidly.

102 Chemical engineer and chemist. Expert in boiler waters and fuels, physical and chemical tests of materials of all kinds. Ten years professor of chemical engineering in live technical school. Consulting practice. Desires permanent position with large concern where brains and push will lead to high advancement. Best of references from present position.

103 Mechanical engineer with experience in designing, purchasing, general business and selling, wishes to associate himself with an eastern engineering or manufacturing concern as assistant to president, purchasing agent or mechanical engineer, or manager of branch office. At present employed. Age 35. Can furnish entirely satisfactory credentials on all scores.

104 Graduate in mechanical engineering, Mass. Inst. Tech., with 20 years of varied experience as manager and engineer in the design, operation and superintendence of construction of machinery, desires to take up similar work, particularly that requiring the improvement of existing machines or processes, and the invention of new devices. Patentee of a number of devices which have been commercially exploited.

CHANGES OF ADDRESS

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BOLAND, Frederick A. (1902), present address unknown.

BROOKS, Henry K. (1907), 18 Morningside Ave., New York, N. Y.

BURBANK, Louis S. (1898), M. E., Draper Co., *and for mail*, 20 Bancroft Park, Hopedale, Mass.

CASH, Arthur Wise (1899), Mech. Engr. and Mfg., Pressure Regulating and Special Valves, 313 Market St., Newark, N. J.

COMSTOCK, Louis K. (1902), Pres., L. K. Comstock & Co., Inc., 50 Church St., New York, N. Y., and *for mail*, 195 Fernwood Ave., Upper Montclair, N. J.

DEHAVEN, Irvin C. (Junior, 1907), Dist. Mgr., A. Sorge, Jr. Co., 525 State Life Bldg., Indianapolis, Ind.

DOYING, William Albert E. (1907), Asst. Inspg. Engr., Isthmian Canal Commission, Washington, D. C.

HALL, Robert E. (1898; 1905), Secy., N. Y. Steam Fitting Co., 90 West St., New York, N. Y., and *for mail*, 11 Park Lane, Plainfield, N. J.

HAYWARD, Sterling F. (1903), Treas. and Genl. Mgr., Connelly Ir. Sponge & Gov. Co., 50 Church St., New York, and 64 Locust Hill, Yonkers, N. Y.

HERBERT, Frederick Davis (1899; 1907), N. Y. Mgr., Terry Steam Turbine Co., 90 West St., New York, N. Y., and *for mail*, Hewitt, N. J.

HOLEMAN, Louis A. (Junior, 1899), present address unknown.

HOXIE, Geo. L. (1893; 1904), Engr. and Contr., Room 1663, 50 Church St., New York, N. Y., and 99 Clarewill Ave., Upper Montclair, N. J.

KENYON, Alfred Lewis (1904), Ch. Engr., Empresas Electricas Asociadas, Box 695, Lima, Peru, South America, and 452 S. Lincoln, Denver, Colo.

KNOX, S. L. Griswold (1892; 1901), V. P. and Ch. Engr., Bucyrus Co., S. Milwaukee, and *for mail*, 232 Biddle St., Milwaukee, Wis.

LAUER, Conrad N. (Associate, 1903), Mgr., Dodge & Day, Washington Bldg., 608 Chestnut St., and 2217 Estaugh St., Philadelphia, Pa.

LEVIN, Arvid Michael (1894). Mech. Engr., 910 Monadnock Bldg., Chicago, Ill

LOFTS, David (1901), 4300 Ellis Ave., Chicago, Ill.

McELROY, Jos. A. (1895), Dir., Macartney, McElroy & Co., Ltd., Caxton House, S. W., London, England.

McMULLEN, Vincent E. (Associate, 1907), Experimental Dept., Fairbanks, Morse Mfg. Co., and *for mail*, 810 E. Grand Ave., Beloit, Wis.

MANNING, Harry G. (1896), Engr. Water Bureau of City of Pittsburg, and *for mail*, Box 172, East Liberty Sta., Pittsburg, Pa.

MITCHELL, Albert E. (1891), The Wyckoff Pipe and Creosoting Co., Inc., and *for mail*, Strawberry Hill Ave., Stamford, Conn.

MUCKLE, John S. (1904), Mech. Engr., West End Trust Bldg., and 2023 Walnut St., Philadelphia, Pa.

NINDE, Wm. Edward (1899; 1903), 614 Ulster St., Syracuse, N. Y.

NOLDE, Frederick (Junior, 1901), Sales Agt., De La Vergne Mch. Co., 138th St. and East River, New York, N. Y.

PARSON, Chas. H. (Junior, 1906), Secy. and Treas., Parson Mfg. Co., Singer Bldg., New York, N. Y.

PATTERSON, A. W. Jr. (1897; 1903), Mgr., Invincible Elec. Renovator Sales Co., De Graaf Bldg., and 462 Hamilton St., Albany, N. Y.

PHILLIPS, Ellis L. (Junior, 1901), Cons. Engr., Room 1663, 50 Church St., and 622 W. 135th St., New York, N. Y.

PULSIFER, Harold M. (1907), Pres., Automatic Sprinkler Constr. Co., 206 La Salle St., and 438 Elm St., Chicago, Ill.

RONEY, William R. (1889), Mech. Engr., Westinghouse Mch. Co., 165 Broadway, and Endicott Hotel, New York, N. Y.

RUTHERFORD, Gordon S. (1901; 1907), Caustic Dept., Solvay Process Co., Syracuse, N. Y.

SEARS, Richard H. (Junior, 1901), Genl. Sales Mgr., Dean Alvord Co., 277 Broadway, New York, N. Y.

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STARR, John Edwin (1905), Pres., Starr Engrg. Co., 50 Church St., and 14 W. 12th St., New York, N. Y.

WHITTED, Thomas B. (1900; 1903), Thomas B. Whitted & Co., Piedmont Bldg., Charlotte, N. C.

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